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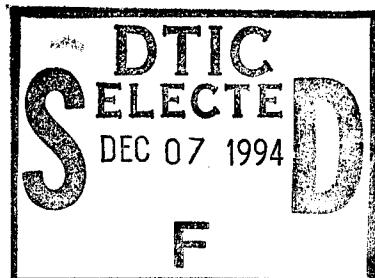
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Monterey, California



THESIS

MODELING CIVILIANS AND THE
CIVIL-MILITARY INTERACTIONS

by

Timothy J. Muehl
September 1994

Thesis Advisor

Samuel H. Parry

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MODELING CIVILIANS AND THE CIVIL-MILITARY INTERACTIONS

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Submitted in partial fulfillment
of the requirements for the degree

MASTER OF SCIENCE IN OPERATIONS RESEARCH

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ABSTRACT

This study proposes a methodology for modeling civilians and their interactions with military units. The sponsor for this research, United States Special Operations Command, requested development of a model to add civil affairs, civil-military operations, and psychological operations functionalities into Joint Theater Level Simulation (JTLS). Inclusion of this capability gives joint staffs a training tool with a fuller representation of the environment currently encountered by the military. The same measures of performance cannot be used for civilian and military units, since civilians are free to waive their membership to a civilian unit. The measure of performance for a civilian unit that defines its continued existence is its well being. Well-being is a function of the current, near term, and long term availability of items essential to civilians. Well being is used as an index for behaviors such as generating displaced civilians, or willingness to cooperate with military forces. A psychological operations campaign directed against a civilian unit is modeled as an attempt to shift a civilian unit's perception of it's well being. Modeling civilians extends the environment currently represented in simulations to include scenarios encountered by the military in the post cold war world.

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EXECUTIVE SUMMARY

This study develops a methodology for modeling civilians and the interactions between civilians and military units in a theater level model. The study was done at the request of United States Special Operations Command (USSOCOM). USSOCOM requested development of a model to add civil affairs (CA) and psychological operations (PSYOP) functionalities into a theater level simulation. The theater level simulation used in this study as a platform for the methods developed was the Joint Theater Level Simulation (JTLS) version 1.85. JTLS's multi-sided capability enables civilians to be represented as a distinct side. Also the widespread utilization of JTLS in joint staffs, as exercise drivers, and in military schools made JTLS an ideal candidate for inclusion of these functionalities. The methods developed in this study however, are generic and applicable for inclusion into other simulations. The study has focused on two areas: (1) modeling the status of a civilian unit, and (2) modeling the interactions of civilian units with military units. This study's approach to implementing a CA and PSYOP functionality is distinct from previous studies in that the status of the civilian unit is considered.

The measures of performance used for military units such as percentage force available, weapon systems available, and rate of advance cannot be extended to civilian units. Civilian units require an abstract notion of well-being to define their current status. The well-being for a civilian unit is defined based on the current and near term availability of items deemed essential to the members of a civilian unit. If a civilian unit cannot provide these essential items, the members of a civilian unit are free to abandon their membership in that civilian unit to seek out other civilian units capable of providing the essential items. Events such as proximity to combat, which can bring destruction to a

civilian unit also effect a unit's well-being. The well-being of a civilian unit is also defined by the long term perception of how well a civilian unit is doing. Using well-being as a measure of performance the impact of civil-military interactions can be assessed.

If a civilian unit's level of well-being falls, a number of civilians will leave the civilian unit to find another civilian unit capable of providing the essential items needed by the populace. The dislocated civilians generated by this process are aggregated into refugee units. The size of the refugee unit is determined by the level of well-being in the progenitor community. Civilian behavior averse to risk is modeled for civilians leaving a community when level of well-being is high for a community. Similarly when the level of well-being for a community is low civilians will tend toward risk taking behavior. More civilians will leave a community at low levels of well-being since they have little to lose. The behavior of refugee units and their impact on military units is considered. Players interacting with the wargame may direct military units to collect refugee units once detected. Players may also direct military units to evacuate civilian units. Coordination for host nation support and third party support is also considered using a queuing model. Players may choose to arrange for host nation support using CA units. Time required for negotiation with a civilian unit to reach a decision whether the civilian unit will support the military is treated as a two server queue. The time until a decision by the civilian unit is faster if a CA unit is used because of their language expertise and knowledge of local customs and culture. Players must evaluate what their optimal policy is, based on the queue waiting to use the CA unit. The well-being measure of performance also quantifies the effects on a community when a military unit provides or destroys essential supplies in a community. PSYOP directed against civilian units can also be interpreted as an attempt to shift a civilian unit's perception of its well-being.

Modeling civilian units creates a fuller representation of the environment in which the military is operating. Inclusion of civilian units also enables modeling operations other than war. Humanitarian relief and peacekeeping operations can be modeled using the methods developed in this study.

The focus of this study was to develop a methodology to portray CA and PSYOP processes in a theater level simulation. This study approaches the problem by extending the environment currently portrayed in simulations to include a more robust representation of civilians and their interactions with military units. The effects of military actions on civilian units is represented by changes in the civilian unit's well-being. Inclusion of these methods into JTLS requires players to consider the consequences of their actions on the civilian units also represented in the wargame. The methods developed in this study are intended to create an improved training tool for joint commanders and staffs. The methods developed in this study enable modeling scenarios currently encountered by the military in a post cold war world such as peacekeeping missions and humanitarian relief missions. This study also develops a foundation which future studies can use to frame questions and data requirements to quantify the effects of other civil-military interactions.

I. INTRODUCTION

A. OVERVIEW

The military's ability to quickly react to a crisis and operate under extreme conditions has given prominence to a new category of military operations, operations other than war (OOTW). A significant feature of the environment for OOTW is the interaction between the military and civilians in the mission profile. The rising importance of the civil-military interaction has been discerned by the current senior military leadership. Army Chief of Staff, GEN Gordon Sullivan recently ordered the Joint Readiness Training Center (JRTC) to devote a portion of one of its ten annual training rotations to peace enforcement training. One of the goals of this training is to force units rotating through JRTC to consider the effects of their actions upon the local population. [Ref. 1:p. 14] A small village, named Carnis, has been added to the training environment and manned with civilians. The local populace and their government are not the only civilians the military must deal with. Non-governmental organizations (NGOs), such as relief organizations, were also included in the training environment.

The interaction between civilians and military units is not a new matter for the military. However, the post cold war environment has made the civil-military interaction a variable of increasing importance in the successful application of military force to achieve some goal. In recent history the military has begun to transition from considering the interaction between the civilians and military the sole responsibility of special operating forces, specialized in civil affairs (CA), to an operation which may also be required of conventional troops. This observation is not to downplay the increasing and critical role played by special operating forces, such as civil affairs units, but to point out

that all military forces must now be cognizant of the interactions of military units and civilians. Military units have with a quickening pace have been called upon to perform OOTW. A characteristic feature in the OOTW environment is the presence of civilians. Figure 1 illustrates the surge of OOTW requiring major deployments of troops and assets. The increasing requirements for military units to support OOTW underscores the importance of considering the civil-military interaction in current and potential uses of military forces throughout the globe. OOTW are not necessarily independent stand alone events.¹

In fact these operations other than war may precede and/or follow war or occur simultaneously with war in the same theater. [Ref. 2:p. 13-1]

Conflicts such as World War II, Korean Conflict, Viet Nam, and Desert Shield/Storm all significantly involved interactions with civilians. However, as the size of today's military decreases, the effect of civil-military interactions on military operations increases.

Of concern to today's leaders is how much additional training time is consumed conducting training such as peace enforcement. Leaders want to ensure today's military has "enough training to successfully perform real world peace operations without dulling the combat edge."² The drawdown of resources available to military leaders has increased the use of computer simulations and wargames for planning and training soldiers. Civil-military operations and psychological operations (PSYOP) are not represented in most current simulations or wargames. Integrating the interaction between civilians

¹ In recent history OOTW have followed conflicts. Operation Promote Liberty followed operation Just Cause and operation Provide Comfort in Northern Iraq followed Desert Storm. OOTW in Somalia could have preceded a major conflict. Initial use of the military in Viet Nam could also be considered as OOTW.

² Comments by commander of opposing forces (OPFOR) of JRTC. [Ref. 3:p. 14]

and military units into wargames and simulations enhances the ability and efficiency of the military to train. Including the capability to model civilians

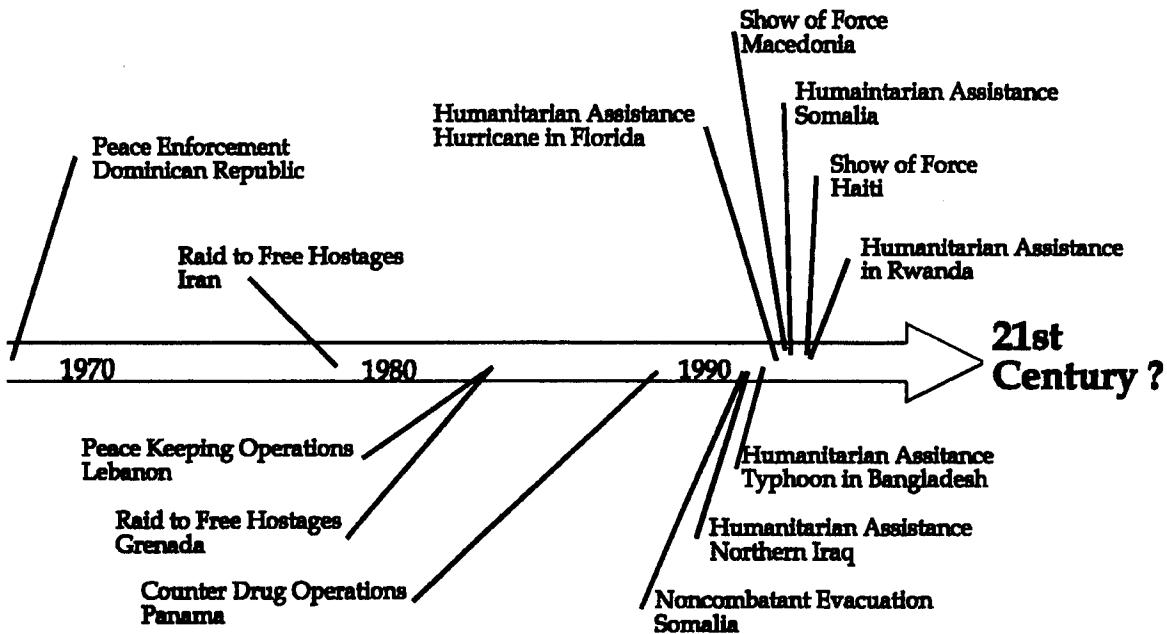


Figure 1. Increasing Pace of Operations Other Than War (OOTW)

enhances the realism represented in current wargames and simulations by modeling the environment across the operational continuum, to include the environments of special operations low intensity conflict (SO/LIC) and OOTW.

This study develops an approach for modeling civilians aggregated into units or communities and their interactions with military units in a theater level model. Included in civil-military interactions are some aspects of the CA, PSYOP, and OOTW missions.

Civil Affairs: Activities that establish, maintain, influence, or exploit relations between military forces, civilian authorities, (both governmental and nongovernmental) and the civil populace... in the military's area of operations. [Ref. 4: p. 120 and Ref. 5:p. 1-1]

Psychological Operations: Planned operations to convey selected information and indicators to influence the emotions, motives, objective reasoning, and ultimately the behavior of foreign governments, organizations, groups and individuals....[Ref. 4:p. 125]

Today the Army is often required, in its role as a strategic force, to protect and further the interests of the United States at home and abroad in a variety of ways other than war. ... Operations other than war include, but are not limited to ... Humanitarian Assistance and Disaster Relief,... Peacekeeping Operations....[Ref. 2:pp. 13-0 to13-7]

This paper is not an attempt to model all CA, PSYOP, and OOTW missions, but will focus on modeling the behavior of civilians. The behavior of civilians creates the environment which defines the effects of CA, PSYOP, and OOTW missions. These effects or civil-military interactions are considerations increasing in importance to the military. This study is a proof of principle that this approach to modeling civilian behavior enables a fuller representation of the environment in which the military operates. If recent history is an indicator, the future includes an increasing number of interactions between the military and civilians.

B. BACKGROUND

Studies done to date on civil-military interactions have focused on force structure of civil affairs units. Recently efforts have been made to quantify the value or effect of planning and implementing a civil-military operations functionality into military campaigns. The most significant obstacle to modeling CA and PSYOP is that limited data have been collected to examine the impact of these processes on military operations.

Modeling of civilians has not been a priority until recently. Attrition, detection, and mobility processes have been the focus of modeling efforts. Two simulations recently added the capability to portray civilians on the battlefield.

Joint Theater Level Simulation (JTLS) version 1.85 has included a representation of civilians. Corps Battle Simulation (CBS), a member of the Army's Family of Simulations (FAMSIM) also recently implemented the capability to model civilians in a limited manner.

Several simulations currently portray the political aspect of the civil-military interaction. Regional Security Strategy Implementation Analysis (RSSIA) is a model used to evaluate a host nation for a region of the world in terms of political stability, socio-economic potential, and importance relative to US interests. Regional Development Simulation System (RDSS) is a model of lesser developed nations, which can be used as decision aid for various policy alternatives.

What is not available is a training tool capable of representing the interactions of civilians and the military at theater level for unified commanders and their staffs.

C. PROBLEM

1. Recent Events

Recent military operations in Panama, Southwest Asia, Somalia, and Rwanda have all required substantial interaction with civilians. These operations illuminate how including civil affairs staff planning and incorporation of CA and PSYOP units can contribute to the successful execution of military operations.

It must be noted however, the civil affairs planning, even for these recent operations in which civil affairs (CA) played a key role were not well done nor completed in timely fashion... Many major headquarters lacked and still lack experienced civil affairs staff officers. [Ref. 6:pp. 1-23 to 1-24]

Integrating civil-military interactions and civil affairs into a joint theater simulation will enhance the readiness of regional unified commands by allowing joint staffs to train for their regional missions with CA and PSYOP capability. It also affords staffs the ability to wargame various courses of action and force mixes prior to an actual conflict.

The drawdown of resources available to military leaders has increased the use of computer simulations and wargames for planning and training of soldiers, leaders, and staffs. The increasing importance and reliance on simulations as training tools has driven simulations to characterize an increasing number of the variables of military campaigns. The expanding opportunities, especially in OOTW, for military forces to have direct interaction with civilians now necessitates the inclusion of civilians into simulations and wargames. CINCs have identified a requirement for simulations and wargames to represent CA and PSYOP functionalities.[Ref. 6:p. F-4, Ref. 7:p. E-4] This study approaches the problem by modeling civilians and their interactions with military units.

2. Problem Statement

The J-5 at United States Special Operations Command (USSOCOM) would like to integrate the interactions between civilian and military units, including a civil affairs and psychological operations functionality, into current simulations and wargames. USSOCOM would like to be able to represent CA , PSYOP, and OOTW missions in a currently fielded theater level simulation. JTLS is the theater level model in use at USSOCOM, and is used by many of the regional CINCs. JTLS is therefore the preferred candidate for inclusion of algorithms developed.

D. RESEARCH OBJECTIVES

The focus of this thesis will be to develop an approach for modeling the interaction between civilians and military forces at the theater level. The development of this capability provides a proof of principle that soft factors can be modeled and extends the usefulness of wargames and simulations as training tools. It enables players to depict CA, PSYOP, and OOTW missions in current theater simulations. As an example, it will be possible to model humanitarian relief operations in a high intensity combat zone, similar to missions currently conducted by United Nations troops in the former Yugoslavia. The objective of modeling civil-military interactions is divided into the four subobjectives described below.

1. Modeling Civilian Behavior

The first subobjective is to present an approach to modeling the behavior of civilians. For a model at theater level, civilians are aggregated into moving units or stationary communities. Civilian units and communities do not operate using the same measures of performance as military units. The behavior for a civilian unit is different from a military unit because the behaviors of individual civilians are different than the behaviors of soldiers within a military unit. As an example, soldiers are required to obey the orders and directives of their commanders, while civilians have a much larger degree of freedom in choosing whether or not to comply with the desires or directives of their leadership. The amount of freedom available to civilians depends upon how much control the government can exert over its constituents. The amount of control a government can exert is related to the happiness or well-being of the governed populace. The well-being of civilians is modeled considering the implications of how civilians logically support themselves and the availability of items defined as essential to civilians.

2. Modeling the Civilian-Military Interaction

Once the behavior of civilians is accurately portrayed, the implications of the interplay between military units and civilians is represented. Generic algorithms to support representation of the effects on military operations by dislocated civilians or refugees are modeled. The capability to conduct military missions involving civilians is also realized. Noncombatant Evacuation Operations (NEO) is an example of a military operation which involves an interaction between civilian and military units. The logistics for military units can be enhanced by requesting support from civilian units. Military units are able to coordinate for host nation support or third party support from civilian units. The ability to affect a side's perception from the availability or denial of information from civilian sources is also modeled. It is also necessary to model denying civilian resources to an enemy. An example is a military unit withdrawing from an area and destroying the local civilian fuel stocks, to deny their use by the enemy.

The result is a reasonably correct representation of these interactions between civilian units and military units. The following list is a summary of the civil-military interactions modeled in this study with generic algorithms.

- Dislocated Civilians (DCs): marshaling and control of dislocated civilians. Includes identification, collection, and movement of dislocated civilians to a secure location. These activities include providing for security, food, water, shelter, health care, etc.
- Noncombatant Evacuation Operations (NEO): assistance and information to help the populace evacuate potential combat areas.
- Coordination for Host Nation and Third Party Support (HN/TPS).
- Deny local resources to the enemy forces.

- Deny the enemy access to intelligence information from host nation sources and improve intelligence from host nation sources regarding enemy disposition.
- PSYOP operations directed against a civilian unit.
- Humanitarian Assistance operations.
- Peace Keeping Operations.

3. Ensure Compatibility of Algorithms for Inclusion into JTLS

The test bed identified for initially including these algorithms is JTLS. All of the algorithms developed will be consistent for easy inclusion into the architecture of JTLS. Flowcharts are used to illustrate the logic and interactions within the overall JTLS structure.

4. Verify Through Expert Review

The fourth subobjective in the preparation of this prototype is to verify logical correctness using expert review USSOCOM.

E. ASSUMPTIONS

The assumptions made for this research are:

- The algorithms developed which depict the civil-military interaction can be coded and incorporated into JTLS without significantly slowing execution of the game.
- The well-being or extent that civilians will remain in a community/unit and follow the directives of its leaders can be represented by a function.
- The representation of factors, and civilian response to levels of these factors is reasonable.

- The function that determines well-being identifies the most critical factors, and the weights for each component are reasonably correct.

F. LIMITATIONS

The civil-military interaction modeled is limited to the doctrinal base of U. S. forces. Although some simulations and wargames are currently capable of playing multi-sided coalition warfare, the only mission profiles modeled are those which follow doctrine adopted by U. S. Forces. Other means of dealing with civilians, which may involve forced labor camps or internment, are not modeled. Application of PSYOP in this study is only considered when directed against a civilian unit.³

G. SCOPE

This research focuses on modeling civilian behavior immediately prior to, during, and immediately following a high intensity conflict, or in situations where civilian's behaviors have been lowered to a survival mode. The well-being function must be modified to extend the method developed in this study throughout the operational continuum. Specifically the well-being function must address the value of accumulating assets or wealth, which is desirable for civilians during periods which are politically stable.

H. SUMMARY OF APPROACH

The lack of data collected on the effects of CA and PSYOP is an obstacle to modeling its process and impact. The data requirements to measure the impact of CA and PSYOP are uncertain, because the CA and PSYOP processes are unlike any other processes (attrition, detection, & resupply) common in military models. The lack of data regarding the effectiveness does not, however, prevent

³ A discussion of PSYOP modeled military units is presented by CPT Pecot in Ref. [8].

the CA and PSYOP processes from being modeled. Once the process has been modeled, data requirements to quantify the CA or PSYOP process can be identified. This iterative strategy can further refine the model, and may provide insights on data requirements and approaches to collect the data. This effort is a first generation attempt to model the complex interactions between two very different groups. The process can be expanded and further refined in follow-on work. It should be noted that some notion of the art and science of its application and effect has been captured by soldiers in CA units who have been deployed to Just Cause, Desert Shield/Storm, and Somalia. These subject matter experts can provide insights regarding what has worked, what has not, and why. Additionally the social sciences may provide information regarding the human behavior.

This research began with an overview. Chapter II is a review of literature with respect to modeling civil-military operations, civil affairs (CA), and psychological operations (PSYOP). The review includes an overview of JTLS.

Chapter III outlines the methodology for modeling the behavior of civilians. This chapter develops the algorithms used to evaluate the level of well-being for each civilian unit. The level of well-being for each civilian unit can then be used as a factor that determines how effective the interactions between the military and specified civilian units are. A section discusses an implementation of PSYOP directed against a civilian unit, attempting to alter the community's perception of its well-being.

Chapter IV develops algorithms that models the processes of interest to the sponsor, occurring between military and civilian units. This chapter approaches the interaction from the military unit's perspective. Military units can be tasked to perform required actions. The level of well-being for the specified civilian unit determines the response or subsequent behavior of the community in the wargame or simulation.

This study concludes with Chapter V, which provides conclusions and recommendations. Areas for further study are identified. Data that can be collected to refine and enhance this study are also proposed.

II. LITERATURE REVIEW

A. INTRODUCTION

It is widely accepted throughout the military that civil affairs and PSYOP act as force multipliers for military units. One of the first attempts to quantify the effects of implementing a CA program was proposed by CPT Andrew Yee in September 1993. [Ref. 9] CPT Yee used JTLS as the testbed for his methodology. CPT Matthew Pecot also recently investigated the potential for implementing a functionality for PSYOP in JTLS. [Ref. 8] This study focuses on implementing a model to represent civilians internal to JTLS. The JTLS model, although widely used, is a extremely large and complex model designed to run on a VAX 8600 series computer. [Ref. 6:p. B-5] The structure of JTLS's architecture and its suitability to be expanded for modeling civilians is reviewed in this section.

B. JOINT THEATER LEVEL SIMULATION (JTLS) VERSION 1.85

The Joint Theater Level Simulation (JTLS) is a U.S. Department of Defense model which is part of the Modern Aids to Planning Program (MAPP). JTLS is used by commanders and joint staff planners to develop and analyze operations plans for theater level operations.⁴ A wide range of joint organizations and schools currently use JTLS as a planning and training tool. Several key users include: USLANTCOM, USCENTCOM, USEUCOM, USSOCOM, USSOUTHCOM, the Joint Warfighting Center, SHAPE, Army War College and Combined Forces Command/Korea. [Ref. 6:p. B-5] . Corps Battlefield Simulation (CBS) is a derivative of JTLS [Ref. 6:p. 3-13] algorithms developed for JTLS in this study may also be applicable for use in CBS.

⁴ JTLS is used extensively as a exercise driver.

JTLS is computer assisted simulation that can model multiple (up to ten) sides. [Ref. 10:p. 4] This multi-sided capability enables JTLS to portray coalition warfare. JTLS is a man-in-the-loop or interactive program. Players control ground, air and naval units through tasking orders. Units are typically aggregated to brigade or regimental level.

Ground units include armored, infantry, marines, and artillery. Other ground units represented include air defense artillery, attack helicopters, and engineers. Logistics units are represented and are played through player input with tasking orders or in an automated mode. Air elements are represented from the Army, Air Force, or Navy. The level of resolution for air units includes airbases and air wings, which provide logistics and command and control down to squadrons. Players provide input in the form of air tasking orders (ATOs). ATOs are used to assemble air mission packages composed of specific numbers and types of aircraft tailored for mission requirements. Sixteen mission types and various load configurations enable significant player interaction in the mission planning process. Naval operations include carrier air operations, amphibious operations, submarine warfare, sea lift and naval gunfire. The level of resolution for naval forces is individual ships. Civilians and noncombatants are also represented as a separate side with the color white (Geneva Convention).

Terrain in JTLS is also typically aggregated into a 16.5 kilometer hexagon. The terrain of the hex is classified into one of fifteen types. The terrain classification impacts a unit's mobility. Several units may concurrently occupy a hex, but mobility is penalized as a result of congestion. Currently terrain data bases exist for Europe, Korea, Central America, and Southwest Asia.

[Ref. 11:pp. 2-2,2-3]

The design of JTLS is based on an object oriented approach as illustrated in Figure 2. [Ref. 12] The object oriented design has enabled maximum flexibility for modeling the large number of entities on a theater level

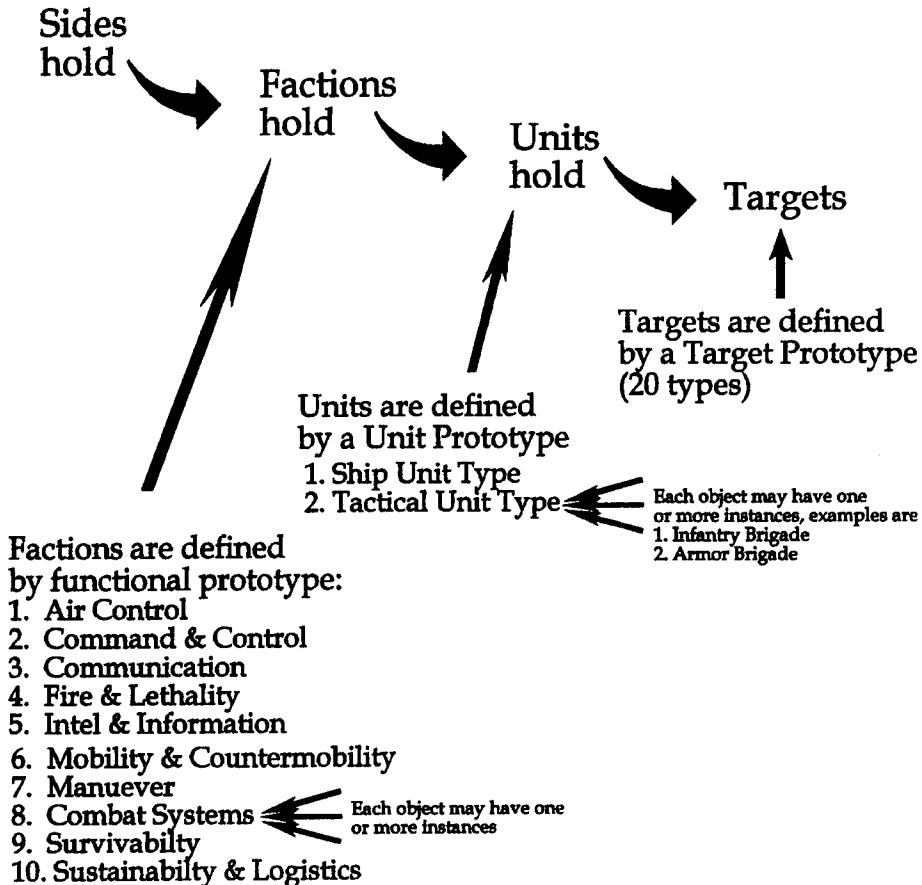


Figure 2. Object Structure of JTLS

battlefield. The object hierarchy has reduced the size of the database needed to represent the large number of units on a theater level battlefield. Sides are composed of an unlimited number of factions. Factions are further templated by 10 objects (functional prototypes) that are built from the Army's Battlefield Operating Systems (BOSs). [Ref. 10:p. 3] These functional prototypes define the capabilities that exist for a faction. One instance of the functional prototype Combat Systems may enable a faction to be equipped with T-72 tanks and BMPs.

A second instance of the Combat Systems functional prototype would enable a faction to be equipped with M1A1 tanks and Bradley Fighting Vehicles. The unit prototype acts as a unit's Table of Organization and Equipment (TOE) and defines what is actually on hand for a specific type of unit.

The multi-sided capability of JTLS has created an opportunity to create civilian units using a separate side for civilians. Using JTLS architecture, the civilian side can have factions, units, and targets. The organization of JTLS as a combat model does not extend without difficulties to include civilians. Civilian units cannot be evaluated using the same measures of performance military units use. Developing measures of performance for civilian units is the focus of this study.

C. AN APPLICATION OF FUZZY SET THEORY

A study by CPT Andrew Yee proposed a model for implementing a CA functionality into JTLS. [Ref. 9] CPT Yee determined that no previous studies had been able to quantify the effect of CA. CPT Yee's approach was to model the CA process by considering the attributes of civilians as they relate to the military commander. Tasking orders used for input enabled players to direct military units to conduct twelve possible CA missions. Two key attributes that defined civilians with respect to a side were the willingness to cooperate and displacement. The variable, *displacement*, determines when a unit of dislocated civilians is created. These two variables and other database fields described the reaction of civilians to military units conducting the assigned CA missions. Due to the subjective nature of the variables, *willingness to cooperate* and *displacement*, fuzzy theory was employed to estimate values for these parameters.

The variable *Willingness to Cooperate* is evaluated by calculating the fuzzy weighted mean for a set of factors using fuzzy addition, multiplication and division. The set of factors that contribute to *Willingness to Cooperate* for one side,

{PSYOP, physical condition, combatant operations, coalition operations, humanitarian assistance, and long standing relationships} are assigned weights of significance by subject matter experts (SMEs). Data from SMEs also were used to construct a range of values that translates into 11 fuzzy linguistic variables. The fuzzy variable for each factor is then used to determine a fuzzy weighted mean. The fuzzy weighted mean is then translated back into a numeric value by Monte Carlo methods for the range specified for the resulting fuzzy linguistic variable. This numeric value then represents a civilian unit's willingness to cooperate.

This method provides a measure of how effectively a military unit is accomplishing a CA mission. It is not a realistic representation of how the civilian unit is affected by events occurring in a wargame. The model developed in this study will focus instead on modeling the environment that shapes a civilian unit's behaviors. This approach requires looking at civilian units from a civilian perspective. In the model developed in this paper, the effectiveness of a CA mission depends on whether it improves the well-being of the civilian unit. CPT Yee's methodology is based on how effective a military unit is when conducting a CA mission based on input from SMEs. By modeling the environment, the benefit of representing OOTW is also included in addition to the CA process. Work by CPT Yee on the player interface and tasking orders can be implemented in this study.

D. COMPUTER SCIENCE CORPORATION STUDY

Two studies, one on PSYOP and another on CA, were conducted during the period of January to November 1992 by Computer Science Corporation (CSC) under a MAPP contract. [Ref. 7 and Ref. 6] Objectives of the studies were:

- Defining and validating the CA and PSYOP mission.
- Defining mission/tasks for simulation.

- Review current conflict models for feasibility of simulating CA and PSYOP processes and effects.
- Review historical data for impact of CA and PSYOP effects on conflict processes.
- Quantify CA and PSYOP effects and define generic routines and algorithms to simulate these effects into recommended models and simulations. [Ref. 6 and 7 p. X-1]

Both studies concluded that CA and PSYOP functionalities are desired for inclusion into current simulations by the CINCs, and could be included in several currently available models. A number of generic algorithms were presented for possible inclusion into currently fielded simulations. The methodology presented by CSC also focused only on the military unit in the civil-military interaction. The algorithm for CA was a generalized algorithm for mission effectiveness for the CA unit. The parameters included: Q , the unit quality; S_a , the actual size of the unit; S_r , the size required for the unit to accomplish a mission; a constant K , the desired maximum level of effectiveness for a unit; and a parameter, λ , determined in equation 1.

$$\lambda = \left(\frac{Q}{S_a^2} \right) \left(\frac{S_r}{S_a} \right) \quad (1)$$

The parameter λ is then used in equation 2 to determine the effectiveness of a CA unit over time. The result is a response curve of the effectiveness of a military unit in accomplishing its mission.

$$E = Ke^{-\lambda t} \quad (2)$$

Dimensional analysis of equations 1 and 2 are not consistent with this finding, but it is critically important to note that how the civilian unit is affected is not represented in the algorithm. The impact of civilians on military units depends on how quickly a CA unit reacts to a situation and how effective the CA unit is. No consideration is given to the status of the civilian unit. In reality if a civilian unit has plenty of food, the impact of a military unit giving out high protein biscuits may not be realized. In the same manner if a civilian unit is starving, providing food several hours later than scheduled may not have the loss of effectiveness implied by this model. The methodology developed in this study attempts to develop measures of performance for civilians that enable military units to interact in a realistic manner with civilian units.

III. METHODOLOGY FOR MODELING CIVILIANS

A. INTRODUCTION

The status of a military unit depends upon maintaining its available firepower, the personnel necessary to operate, the ability to execute assigned missions, and a level of supplies necessary to conduct operations. The status of civilians grouped into a community (or unit) is not accurately or appropriately evaluated by these measures of performance. Civilians organize or aggregate themselves into communities or units to improve their well-being. If a civilian's well-being is no longer improved or adequately maintained through membership in a community, civilians are free to leave in search of other means to maintain or improve their well-being. A well-being function is defined to model the level of well-being for a community. Social scientists and economists have long recognized the necessity for the accounting and measurement of the well-being of communities. Economists have focused their definition of well-being on the flows of material and services, while social scientists have concentrated on quality of life and social indicators.

The function that defines the well-being of civilians during peacetime must focus on economic competition and quality of life. The well-being function for civilians within an area of military conflict must be defined or weighted differently than the measures of well-being used during peacetime. The well-being function for a civilian community must transition from an economic and quality of life basis to a survival basis upon the outbreak of hostilities. This survival basis is much more rudimentary than the quality of life paradigm social scientists and economists measure. As the conflict develops for civilians within the zone of hostilities, the importance of traditional economic and social issues decreases while the importance of basic survival needs increases. As an

example, the value of money decreases relative to the value of food, water, and shelter. Capturing the level of well-being for a civilian unit reflects the current status or availability of these survival needs for that unit. The level of well-being for a civilian unit captures the degree of starvation or privation currently endured within the unit. A community, as a consequence of low levels of well-being, may generate refugees. The departure of refugees from a community lowers its population until the community reaches a level of well-being that the community can sustain. The level of well-being provides a relative measure of how stable communities are and provides a means of modeling the decline or improvement of society's capability to meet its basic needs. The interaction between military forces and civilian unit can degrade or improve the level of well-being enjoyed by a civilian unit over time.

B. CIVILIAN WELL-BEING FUNCTION

For this study civilian units are arranged into two categories. A civilian unit which is stationary is classified as community. Otherwise a civilian unit is a moving civilian unit. Moving civilian units include refugee units, transportation units, ship crew units, etc. The method of calculating the level of well-being for civilian units depends on the category.

The well-being of a civilian community depends on the availability of items required, thus of intrinsic value, by the members of that community. The well-being of a community is determined by the availability of these items now and in the future. The lack or shortage of essential items is most critical if there is already a shortage impacting the community. Therefore, the current availability or shortage of these necessities has the most weight or impact in a model for the level of well-being of a civilian community. The availability of these items in the near future based on a commitment or scheduled delivery may be somewhat reconciling to a community, but is not as important as whether the

commodities are currently available. The near term outlook which is based upon scheduled deliveries to a community is therefore weighted less than the current availability of the essential commodities. Additionally, a more vague or indistinct perception based upon the recent historical trend of a community's level of well-being has some influence. This perception is based only on the recent trend of the well-being level for the community. Members of a community have more concern about the future levels of well-being than past levels, but the past performance of a community does provide to the membership an indication of the community's potential performance. The long term outlook is not based upon any information specific to the future, rather it relies on past performance of a community's well-being as an indication of the future outlook for a community's level of well-being. This vague notion based upon the recent historical direction or trend for a community's well-being is weighted the least. It can be interpreted as the best guess by the population where their community is heading in the long term future. The level of well-being for a civilian unit is modeled in equation 3, utilizing a weighted mean function. Three variables cu , nt , lt represent, in order, the *current* availability of necessity items, their forecasted availability in the *near term* future, and a perceived availability for the *long term*. The relative importance or contribution of each component is determined by the multiplicative weight for each variable.

$$Well - Being_{Community}(cu, nt, lt) = \frac{(5*cu) + (3*nt) + (2*lt)}{10} \quad (3)$$

The current situation contributes the most to the level of well-being for the community. The near term outlook is based on materials on hand in excess to current needs plus any forecasted arrivals of needed commodities. The near term outlook contributes less to a community's well-being, and the long term

outlook, based only on recent trends, contributes the least of these three components. The three variables are defined such that the range of possible values are positive, bounded between zero and one. The values for the multiplicative weights serve as a starting point in the modeling process and can be refined by further study.

The level of well-being for moving civilian units does not look into the future. The level of well-being for moving civilian units is determined only by the current situation. If players dispatch units with insufficient supplies for their trip at some point in the route the unit's well-being is affected. Equation 4 defines how a moving civilian unit's well-being is calculated.

$$Well-Being_{Moving\ Unit}(cu) = cu \quad (4)$$

The items of value to civilians are defined as the ability to accumulate wealth, an availability of foodstuffs, and a ready availability of shelter.⁵ If these items are available to the members of a civilian unit, civilians retain their membership in the civilian unit. If these items are not available, civilians will discontinue their membership in that unit to find a civilian unit that provides these items. The ability to accumulate wealth includes accumulating money, and other assets. Once a conflict has broken out, the contribution of wealth to the well-being of the civilian unit is diminished. Often this is reflected by a loss in purchasing value of a country's currency in favor of more tangible commodities. This loss of buying power for civilian's currency occurs not only locally to the civilians within the theater of operations, but is also globally

⁵ Availability of medical treatment for civilians may also be considered. Currently JTLS does not explicitly portray medical treatment. This capability may be added to JTLS at a future date and is an issue subject to further research.[Ref. 10 :p 7]

depressed in the world economy. Payment for any services or trade usually requires access to a more stable form of currency, which generally is not available to the members of the civilian units in the theater of operations. The ownership of other financial instruments or assets is similarly reduced in value. Since the contribution of wealth is diminished during times of war, the accumulation of wealth is not considered in this model. In a peacetime or in a SO/LIC environment this variable cannot be ignored. The availability of foodstuffs and shelter during a conflict retains or increases in value to civilians and is therefore essential to a model that represents the level of well-being for a civilian unit. If a sufficient amount of these essential items is provided by the civilian unit to its membership, the civilian membership remains content to maintain their membership within the civilian unit.

The level of well-being for each civilian unit is updated on a daily basis. A daily basis is more than adequate to capture any shifts in a unit's perception of its well-being. The variable that represents the contribution of a unit's current situation, cu is recomputed during each update. The near term situation, nt is recomputed every seventh update (weekly). The long term outlook term, lt is updated monthly. The updates to civilian units all occur at a common time, such as 00:00 on a daily cycle.

1. Current Situation

The contribution to the level of well-being for a civilian unit from the current situation is measured by the current availability of foodstuffs, current availability of shelter, and current distance to events that can bring destruction to a civilian unit. The relative importance between foodstuffs and shelter varies among regional cultures and populations. As an example, shelter may not be as important to people of a nomadic heritage or where the climate is moderate. A very different importance will be placed on shelter by a community rooted in a

Western European culture where a man's home is his castle and he may be very hesitant to abandon his property. For the general case in which the nature of the population is unknown, the weights are assumed of equal importance. If information regarding a specific population is known, the weights can be adjusted accordingly. The current situation is defined by equation 5.

$$cu = \frac{(4*f) + (4*s) + (2*d)}{10} \quad (5)$$

The amount of foodstuffs currently available to the civilian community is represented by f , the current availability of shelter to civilians in a community is represented by s , and d represents the distance to the closest combat.

a Availability of Foodstuffs

The availability of food for the population of a community depends upon the amount of foodstuffs on hand within the community, and the ongoing ability of the community to acquire sufficient foodstuffs to sustain the community's population. Figure 3 illustrates the flows of foodstuffs in a community. A community may acquire foodstuffs by importing needed items from overseas or through local trade with farms and ranches surrounding the community. In times of emergency, foodstuffs may also be supplied from non-governmental organizations such as Care, International Red Cross, or agencies of the United Nations. Aid may also be distributed by military forces conducting humanitarian relief operations, such as operations conducted in Northern Iraq, Somalia, and Rwanda. Concurrently, outflows of foodstuffs for a community include loss due to spoilage, consumption by the population, and foodstuffs appropriated by military units. At the beginning of every update the food on hand (foh) term is computed according to equation 6. The unit of measurement for each term is tons of foodstuffs. The quantity of food on hand

$$f_{oh} = f_{oh}_{prev} + tr + im + rel + \sum_{i=1}^s \sum_{j=1}^f s_{ij} - l - csp - \sum_{i=1}^s \sum_{j=1}^f a_{ij} \quad (6)$$

for a community from the previous day is defined as f_{oh}_{prev} . The variable im represents tons of foodstuffs that arrived during the previous day as the

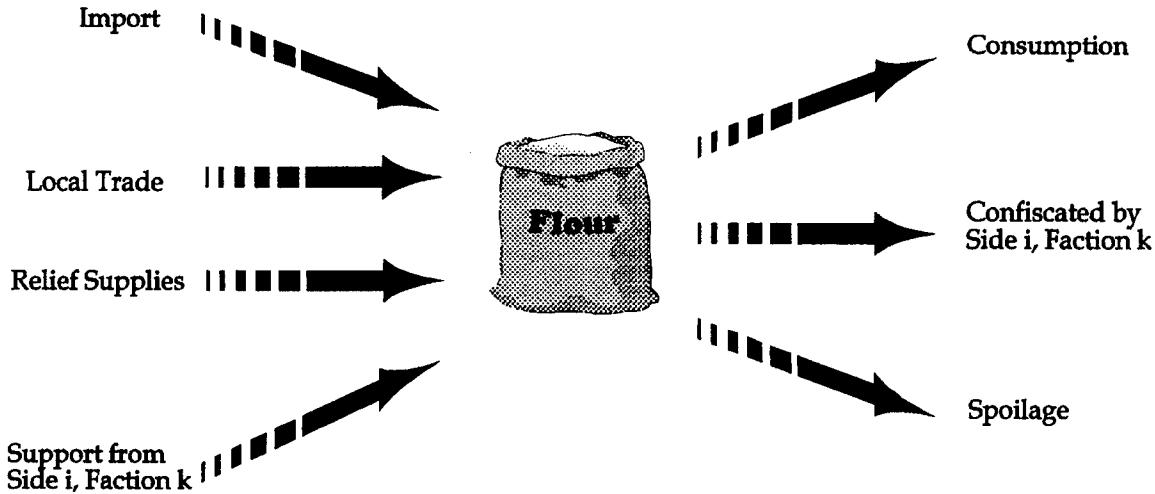


Figure 3. Factors for Updating a Community's Food on Hand

result of a community importing foodstuffs from outside the theater of operations. The variable tr represents the arrivals of any foodstuffs from local farms as the result of trade between the community and farms in the local area. These foodstuffs are aggregates of meat, grains and fruits typically produced by farms and ranches. The variable rel is foodstuffs supplied to communities by non-governmental organizations. The variable s_{ij} represents foodstuffs provided to the community through humanitarian assistance operations by a military unit of side i and faction j . The foodstuffs lost as the result of combat or spoilage is represented by l . The variable a_{ij} represents foodstuffs destroyed or seized from the community by a military unit of side i and faction j .

Consumption of foodstuffs for the previous day is accounted for by the variable csp and is calculated by equation 7. The variable Pop is the current population

$$csp = (pop)(\lambda_f)(1 \text{ day}) \quad (7)$$

or strength of the civilian unit. The rate at which foodstuffs are consumed is λ_f . The rate at which foodstuffs is consumed for civilians is assumed to be the same as for military personnel. The units of λ_f are tons per person-day. The result is that csp is measured in tons.

Communities lack the capability to produce enough foodstuffs to sustain themselves. Each community has an amount of foodstuffs on hand, foh_{Prev} . This reflects the foodstuffs available in stores, warehouses, or held by the members of the community. To replace the foodstuffs consumed, communities rely on commerce to maintain adequate quantities of foodstuffs. Commerce can be in the form of importing foodstuffs from a supplier overseas, or from outside the theater of operations considered in the wargame. Importing foodstuffs is represented by scheduling an event, the arrival of foodstuffs, to an appropriate port of entry into the theater of operations as defined by the wargame. Resupply from imports occurs from either barge or ship. If the quantity of foodstuffs is sufficient, directed resupply of other civilian community units may occur as directed by player input.

Another commercial source of foodstuffs for communities is trade with the surrounding rural areas capable of producing foodstuffs. The variable tr represents the supply of foodstuffs delivered to a community from surrounding rural areas that can maintain a trade relationship with the community. This relationship between communities and the rural agrarian areas that produce foodstuffs can be modeled using a network structure.

The amount of land needed to support a community depends upon whether the terrain is favorable for crop production. In JTLS and other wargames that use a grid system, each grid is given an average or aggregated classification for the type of terrain contained within the grid. The capacity of a grid for crop production is therefore related to the terrain code for the grid. As an example in JTLS, a hex with the terrain code of Open is very suitable for crop production while Open Desert is not capable of large scale crop production. Small scale facilities may be capable of growing foodstuffs in the desert, but not in the scale modeled by a theater level wargame such as JTLS. The terrain represented by the hexes considered capable of producing foodstuffs may be occupied with many small farms, or with a large corporate farm. What type of facility is producing the foodstuffs is below the resolution of the game. It is only important to realize that the hex is capable of producing an amount of foodstuffs. Representing each farm is not desirable and is not consistent with the aggregation used for military forces modeled in the wargame. The limit of resolution that is imposed by the aggregation used within JTLS is the hex. In the same manner that terrain is aggregated, the production from the farms located within the grid must also be aggregated. As an example, the terrain code for Forest does not have a large area of land suitable for farms. There may be some small number of small farms nestled within the forest, but the overall production for the forest grid is smaller than for a grid with the terrain code Open. Therefore the quantity of foodstuffs produced from a grid with the terrain code Forest is small.

Some areas in the world may in fact be suitable for crop production, but are not farmed. These areas are not farmed because there are no large communities nearby that require the foodstuffs that can be produced in this area. The model considers this by ignoring possible production of foodstuffs from additional hexes once a community's needs are met. These areas

are put into production if needed as the result of military conflict in hexes that normally provide a community with foodstuffs. The terrain index only identifies the upper limit for a hex's capability to produce foodstuffs. This capability is degraded by events such as combat, draught, or floods. This can be modeled by adding one field to the terrain data base, a production degradation factor. The production degradation factor varies from 0 to 1. The default is 1, which is no degradation. When a military unit moves through a non-road hex, a degradation factor of 0.9 is applied to reduce crop production. Hexes with roads are not degraded. It is assumed that military units use roads when moving. If combat exists between any two hexes, a degradation factor of 0.5 is applied to both hexes. Long term random events for groups of hexes can also occur. Events such as floods or droughts are modeled in this manner. Hexes affected by floods or draughts are applied a degradation factor of 0.3. Another method of applying degradation factors which can be examined in further work involves applying degradation factors randomly drawn from a normal distribution instead of using deterministic values. To keep this initial study simple, deterministic values of degradation values are used.

JTLS categorizes terrain with terrain index variables.

[Ref. 13:p. 3-3] Their are 15 indices describing different types of terrain modeled in JTLS. These terrain index variables, shown in Table 1, are used for describing mobility and trafficability of hexes, but are also sufficient to identify terrain capable of producing foodstuffs. Table 1 relates terrain codes to tons of foodstuffs produced daily for various regions of the world. Entries for the Table 1 are derived in the appendix at the of this study.

To model the transportation of the foodstuffs from farm to market, a network of nodes connected by arcs is established. As illustrated in Figure 4, each hex represents a node which has an assigned terrain index which determines the hex's capacity for foodstuff production in thousands of tons per

day. The hexes capable of producing foodstuffs are modeled as supply nodes, and the markets (communities) are modeled as demand nodes. The cost on the

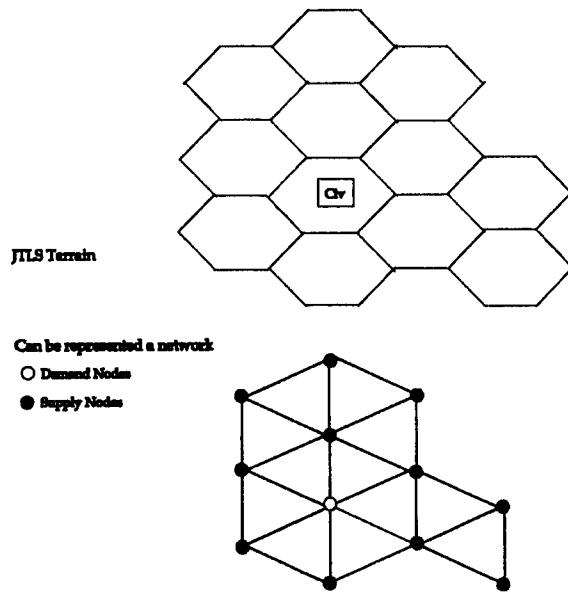


Figure 4. Network Representation of Trade

arc to complete the movement of the foodstuffs to market is the time or distance required to transport the foodstuffs to the community. This distance determines how often a community is resupplied.

Dijkstra's algorithm is then repeatedly applied, identifying hexes supplying a community until demand for the community is met. [Ref. 14:p. 109] This iterative process is performed identifying the closest hexes which are assumed the most cost effective to resupply a community. This process is repeated in sequence for each community to determine the most economical group of hexes needed for each community to maintain sufficient foodstuffs on hand. It is necessary to determine which civilian community units are evaluated first using this process. The community evaluated first will get first choice of which supply nodes with which to conduct trade. To determine the priority of communities for evaluation in this process, it is necessary to model the market

Terrain Name	Terrain Index	Europe	Africa	China
		North America	Asia	USSR
Good Road	1	0.171	0.086	0.090
Poor Road	2	0.180	0.091	0.095
Open	3	0.190	0.096	0.100
Forest Good Road	4	0.067	0.034	0.035
Forest Poor Road	5	0.048	0.024	0.025
Forest	6	0.019	0.010	0.010
Desert Good Road	7	0	0	0
Desert Poor Road	8	0	0	0
Desert	9	0	0	0
Rubbled City	10	0	0	0
City	11	0	0	0
Mountain Good Road	12	0.090	0.005	0.005
Mountain Poor Road	13	0.090	0.005	0.005
Mountain	14	0.090	0.005	0.005
Ocean	15	0	0	0

Table 1. JTLS Terrain Indices and Associated Foodstuff Production

forces that will drive how foodstuffs are actually distributed. Market forces ensure efficient allocation of the foodstuffs produced by the rural agrarian areas. The community with the most immediate need for foodstuffs (lowest availability of foodstuffs, f) provides the highest profit for the seller. The only event that interferes with market forces is the threat of damage or loss of goods due as a consequence of the military conflict. As long as there are no military units in combat that prevent safe entrance to the city, sellers will attempt to move their foodstuffs to the market that maximizes their profit. To model how foodstuffs are allocated in the marketplace, each community is prioritized by the profit that is realized by the seller. The priority in which each community is evaluated is:

- Smallest f where access to community is not impeded as a result of combat between military units.
- Smallest f where the community is partially inaccessible as a result of combat between military units.
- Smallest f where the community is inaccessible as a result of combat between military units.

Dijkstra's algorithm is then used to determine the shortest path between the community and hexes containing a capability to produce foodstuffs (farms). The shortest path(s), calculated by Dijkstra's algorithm, determines which hexes resupply the community, and based on their distance from the community, how often these resupplies occur. If a hex is less than one days travel from a community, deliveries are made on a daily basis.

The availability of food for the population of a moving civilian unit depends on the amount of food on hand. Moving civilian units do not have the capability to conduct trade and have the foodstuffs delivered to themselves. When moving units are dispatched on a mission by a player through a tasking order, sufficient foodstuffs should be on hand in the unit to ensure it can complete its mission. A moving unit can only be resupplied by support from

military units, relief organizations or by foraging for foodstuffs. Foraging for foodstuff provides a small quantity of foodstuffs to moving units when moving through crop producing hexes. The quantity of foodstuffs added to the moving unit by forage is defined by equation 8.

$$for = \frac{Food_{Req}}{3} \quad (8)$$

The factors that impact on the availability of foodstuffs for moving units are illustrated in Figure 5. The amount of food on hand for moving units is computed according to equation 9. The variables defined in equation 9 are the

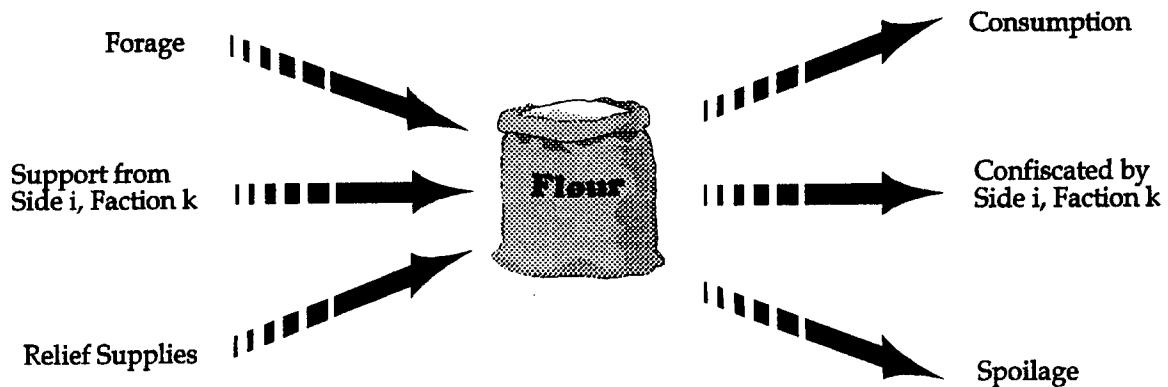


Figure 5. Factors for Updating a Moving Unit's Food on Hand

same as for equation 6 except moving units can add foodstuffs through forage which is defined as for . Equation 9 does not allow moving units to receive foodstuffs from local trade or by importing foodstuffs.

$$foh = foh_{prev} + for + rel + \sum_{i=1}^s \sum_{j=1}^f s_{ij} - l - csp - \sum_{i=1}^s \sum_{j=1}^f a_{ij} \quad (9)$$

Resupply of foodstuffs from a relief organization to a civilian unit is directed by the player controlling the neutral relief organizations (NGOs) through a tasking order. The foodstuffs transferred are taken from the

foodstuffs organic to the NGO unit. The resupply of the NGO unit is conducted as strategic resupply from outside the theater of operations.

Resupply of foodstuffs from a military unit is directed by the player controlling the military unit through a tasking order. This type of action models activities similar to missions conducted by the military in Operations Provide Comfort in Northern Iraq, and Restore Hope in Somalia.

The current availability of foodstuffs for a civilian unit is defined in equation 10.

$$f = \min\left\{\frac{(FOH)}{(Food_{req})}, 1\right\} \quad (10)$$

The tons of foodstuffs needed to support the current population is defined in equation 11 as $Food_{req}$. The variable f is the percentage of foodstuffs on hand

$$Food_{req} = (Pop)(\lambda_f)(1 \text{ day}) \quad (11)$$

needed to feed the civilian unit during the current update period. The variable f is a unitless positive number. If enough foodstuffs are currently available, the index f is equal to 1 and contributes to the overall well-being of the community. If the index falls below 1 the contribution foodstuffs provides to the current well-being of the community is lowered.

b Availability of Shelter

The definition of shelter considered in this model is protection from the elements, a place that civilians may be free from the cold and rain. It does not consider shelter as a safe haven from conflict. Examples of factors that provide shelter for communities include houses, apartments, or tents. In moving

units, factors that can provide shelter include tents, or even trucks when there are eating and sleeping capabilities. Some of the factors that can impact on the availability of shelter in a civilian unit are shown in Figure 6. The factors that remove shelter from a civilian units can be offset by repair of damaged facilities or dwellings, and temporary shelter provided by the military and relief organizations in the form of tent cities.

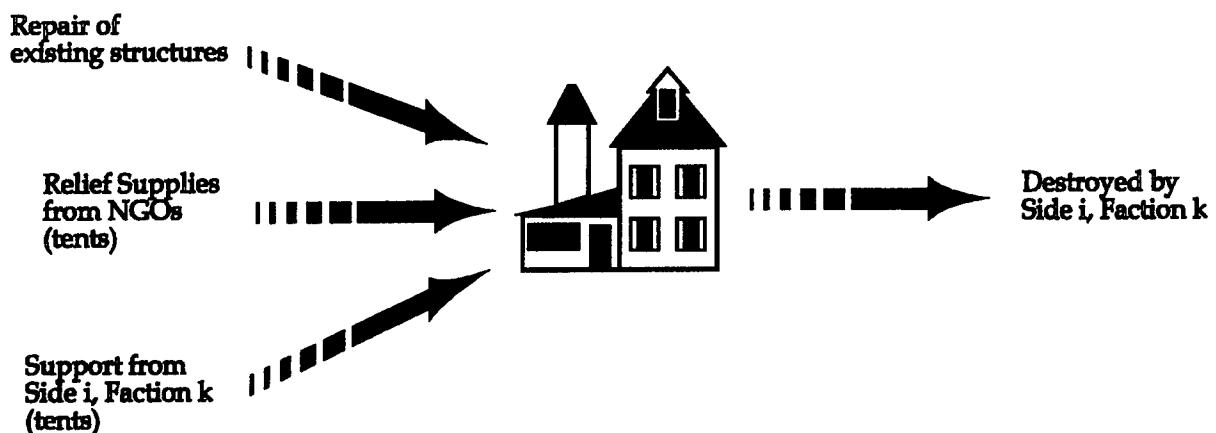


Figure 6. Factors for Updating a Civilian Unit's Available Shelter

In order to model the dynamic nature of the availability of shelter for the civilians in a unit, a unit of shelter must be defined as a target. In this model a unit of shelter is capable of sheltering a household and is referred to as a dwelling. An average household is defined as four persons. Therefore this study assumes each dwelling provides shelter to four members of a community. These dwellings are targets within a civilian unit in the same manner that a tank is considered a target within an armored unit. The JTLS architecture enables each unit to possess a number of targets. The structure of how sides are built in JTLS is shown in Figure 7. [Ref.12] Communities are not pristine units that are free of military targets. In all conflicts, communities have contained targets such as fuel tanks, airfields, and warehouses containing foodstuffs which are of

military value. Frequently, communities were themselves targets because of the great number or density of targets within a community. History has shown that military targets are very likely to occur in the midst of communities and attempts by an opponent to destroy these targets can inflict collateral damage on the community. Targets can also be incorrectly identified with a potential for

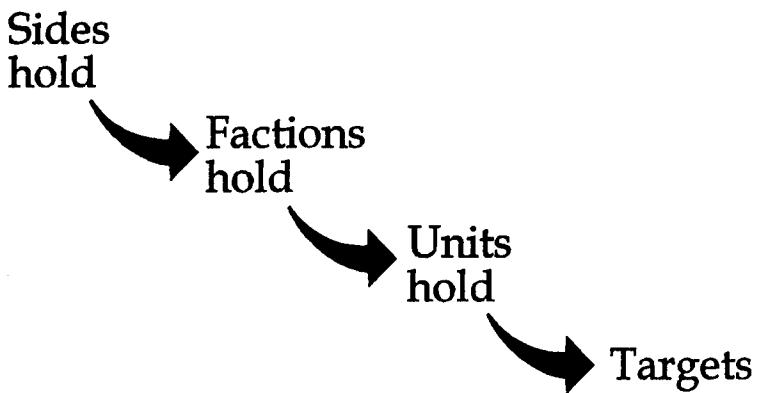


Figure 7. Structure of JTLS

devastating results to the members of a community. The methodology for sensors detecting targets in units already exists in JTLS and can be applied to distinguishing between dwellings and other types of targets such as fuel tanks, airfields, and warehouses containing supply items such as foodstuffs. The targets of military value within a community must also provide some host nation support to the military units within the local area. It then becomes advantageous for the other side to attempt to destroy these targets. The consequence of attacking these targets, however, is the risk of destroying dwellings which, in effect, reduces the level of well-being for the civilians of the community. Adding dwellings as a target also adds the ability of one side to destroy dwellings in addition to other targets in an attempt to force the other side to commit its resources to maintain the well-being of the community. The strategic bombing campaigns of Germany against Great Britain and later by the Allies

against Germany during World War II used these concepts in an attempt to grind down an opponent's logistics system.

Targets located within a community can be attacked by either aircraft or by artillery fire. Collateral damage is determined by monitoring the draw to determine probability of hit on the intended target. If the intended military target is not hit, dwellings are assumed to be hit. The number of dwellings destroyed is computed based on the lethality of the weapon system used. The lethality is reduced slightly to compensate for the assumption of automatic hit on the dwellings target if the intended target is missed.

The dwelling term also is updated during the daily update according to equation 12. The number of dwellings available in a community

$$dw = dw_{prev} - \sum_{i=1}^s \sum_{j=1}^f z_{ij} + rs + \sum_{i=1}^s \sum_{j=1}^f b_{ij} + \sum_{i=1}^s \sum_{j=1}^f rep_{ij} \quad (12)$$

the previous day is defined as dw_{prev} . Shelter destroyed by side i, faction j is defined by z_{ij} . Temporary shelter in the form of tents from relief organizations is defined by the variable rs . Temporary shelter in the form of tents from side i faction j is defined by the variable b_{ij} . Shelter repaired by side i faction j is defined by rep_{ij} .

The available shelter variable, s , is also updated in the daily update before calculating cu . The available shelter is defined by equation 13.

$$s = \min \left\{ \frac{dw}{\left(\frac{Pop}{4} \right)}, 1 \right\} \quad (13)$$

The variable dw describes the number of dwellings a community has for its members. The variable Pop is the current personnel strength for the community.

Since the average household was defined as having a size of four, the number of households is approximated by dividing the population by four. The percentage of households that are in shelter is then determined by dividing the number of dwellings by the number of households. Since there is no advantage to the community that has excess available dwellings, s is constrained to a upper limit of 1.

c. Potential for Destruction from Combat

The possibility of conflict reaching a civilian unit during a given day is measured by d which is an index of the proximity of events that can cause destruction to civilians. The proximity to conflict is calculated using the relationship in equation 14. The distance from the community to the closest

$$d = \min\left\{\frac{d_{max}}{dis}, 1\right\} \quad (14)$$

military units in conflict is defined by dis . The distance the slowest of the two units in conflict can travel in one day is defined as d_{max} . The possibility that two military units can carry their conflict to the civilian unit is gauged by the variable d .

2. Near Term Situation

The near term situation variable from the well-being function is updated every seven days in the model. This variable is weighted less than the current situation, but more heavily than the long term perception because it is based on known information regarding the future. Equation 14 calculates the projected fraction of foodstuff requirements that can be filled for a community for the next

$$fwk = \frac{foh + (7*sch)}{(7*Food_{req})} \quad (14)$$

week. The ability of a community to provide required foodstuffs for the next week is defined as f_{wk} . The amount of foodstuffs scheduled to be delivered daily as the result of crop production is defined as s_{ch} . The amount of foodstuffs required to maintain a community for a day again is defined as $Food_{req}$. The availability of dwellings in a community is defined by equation 15.

$$dwk = \frac{(dw + schdw)}{\left(\frac{Pop}{4}\right)} \quad (15)$$

The expected number of dwellings available within a community, d_{wk} , is defined as dwellings currently available plus any scheduled repair of dwellings defined as s_{chdw} . The near term variable used in the well-being function is defined in equation 16.

$$nt = \frac{(f_{wk}) + (d_{wk})}{2} \quad (16)$$

3. Long Term Perception of Situation

The long term perception term in the well-being function is updated every thirty days in the model. This term is weighted the least because it is not based on any information specifically known about the future, but rather is based only on the current trend in the level of well-being for the community. The trend is computed using a least squares fit of the last three month's levels of well-being. A projected level of well-being is then estimated for the next thirty day update.

As an example, if the level of well-being for the last three, thirty day updates were in order 0.8, 0.83, 0.85. The fit is shown in Figure 8. The value for the variable lt is 0.88 for the next thirty days until the next thirty day update. A maximum value of 1.0 and a minimum value of 0.0 constrain the variable lt to

the same range of values allowed for c and nt . Computation of lt during the next thirty day update is now based on 0.83, 0.85, and 0.88. Clearly when the all

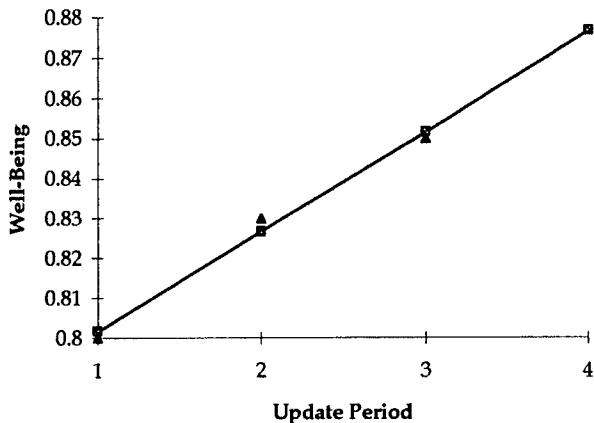


Figure 8. Calculation of lt

the data points indicate a positive or negative slope, the forecast is appropriate. However, if the data points do not appear to define a definite trend, the model's results are still conservative in their prediction. In the example illustrated in Figure 9, despite a apparent change in the slope, the model is slow to react to

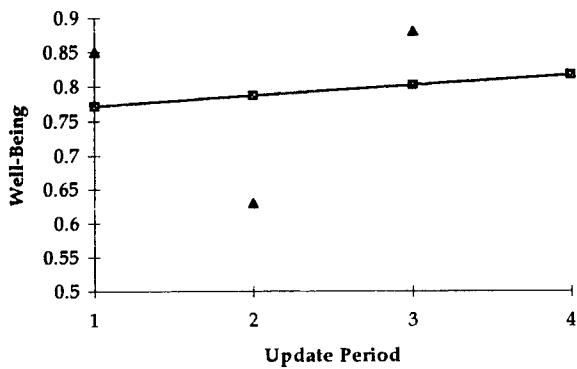


Figure 9. Calculation of lt Using Linear Regression

any changes in direction. The conservative behavior of this model resembles a skeptical public that will believe things are getting better only after the level of

well-being for a community has been raised over a long period of time. For this reason a linear regression model is more appropriate than a nonlinear method.

In Figure 10 the nonlinear method is too optimistic, predicting a value of 1.0 for the community's well being in thirty days. The conservatism of the linear model

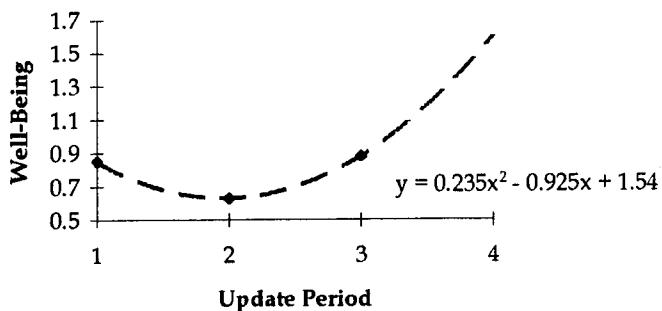


Figure 10. Calculation of *lt* Using Nonlinear Line Fit

in conjunction with the fact that most people tend to use a linear approach in their forecasts makes a linear regression the model of choice for calculating *lt*.

C. PERCEPTION OF WELL-BEING AND PSYCHOLOGICAL OPERATIONS

The actual level of well-being for a community may be different than the community's perception of its well-being. In order to accomplish this shift in perception, assets must be employed to bias public opinion. Psychological operations (PSYOP) units can be used to undermine the morale and will for civilians to retain their membership in a community. In fact, both sides can utilize PSYOP assets to wage a war of words in an attempt to change the public's perception of its well-being.

In order to facilitate altering the perception a community holds of its well-being, PSYOP units must be dedicated against the target community. Once a

community has been targeted, the effectiveness of the PSYOP campaign is dependent upon the goals of the PSYOP campaign and the effectiveness of the PSYOP unit. Initially a player must identify a civilian unit to conduct a PSYOP campaign against. The objective of the PSYOP campaign is established by the player initiating the PSYOP campaign. The objective is to shift the perceived level of well-being within the designated community to the targeted level of well-being through the use of a PSYOP campaign. The player will have to estimate the actual status of the designated community's well-being and select a targeted level of well-being that is attainable with the effectiveness of the PSYOP assets at his disposal. For players to initiate a PSYOP mission, a *Conduct PSYOP Mission* tasking order is generated. The tasking order must contain the following information.

- What PSYOP units are tasked with the mission.
- What civilian unit is targeted.
- Targeted level of well-being.
- Start PSYOP operations no later than time.
- Mission complete time.

The effectiveness of a PSYOP weapon can be likened to the probability of kill of a conventional weapon system. Once applied, the effectiveness is still random in that its effect is variable. Past cases may have shown a level of effectiveness but environment and population will alter the actual results. The effectiveness of the PSYOP is modeled by conducting a Monte Carlo draw from a uniform distribution between the actual value of well-being function and the targeted value of well-being. For example, if 0.5 is drawn, the change in a community's perception is shifted half way between the actual value and the targeted value. The shift only affects the current situation *cu*. In order to change the long term perception of a community, the PSYOP assets must be left in place over the seven or thirty day periods to achieve lasting results. A long term change is realized

by changing the base of data points from which the long term perception term, lt , is calculated.

IV. METHODOLOGY FOR MODELING CIVIL-MILITARY INTERACTIONS

The previous chapter focused on putting in place the tools necessary to evaluate the status of a civilian unit. This chapter focuses on modeling the interaction between military units and civilian units.

A. DISLOCATED CIVILIANS

Generating dislocated civilians is a process of dividing a civilian unit into several smaller civilian units. The smaller refugee units of dislocated civilians created from a community may eventually combine with other units of refugees (throwing in together) or be absorbed into a community with a level of well-being higher than the refugee's level of well-being. A model of this process first requires generating events for each community. These events represent civilians deciding to leave a community.

Communities decompose into a smaller community and a refugee unit when the community's level of well-being falls. The level of well-being for a civilian community is periodically updated in the same way that supply levels are periodically updated in a military unit. Just as a military unit can fall below a critical threshold which influences its effectiveness in fighting, a community's level of well-being may fall below a threshold that influences how many civilians terminate their membership in a community to search out a different community providing an adequate standard of living.

1. Creation of Dislocated Civilians (Poisson Process)

The events representing de-aggregation of a group of dislocated civilians from a community can be modeled by a Poisson Process. The time between events creating refugee units is sampled from an Exponential Distribution. The decision by individuals to leave their homes and flee does not depend on

previous events, vice what the current situation is within the community. The decision to depart is based on only the current level of well-being of a community. The only distribution which has this memoryless property is the Exponential Distribution. This supports the idea that departures of refugees from civilian communities could be modeled using a Poisson Process.

For theater level models it is necessary to aggregate the departures of many individual dislocated civilians into a refugee unit. The size of a refugee unit must remain consistent with respect to the size of the military units played within the model. If the resolution of military units is brigade level, the size of the refugee unit must be comparable to cause an interaction with the military unit. For example, a refugee unit's aggregated size and footprint on the battlefield must realistically degrade trafficability of a brigade passing through the refugee unit. The size of the refugee units generated by a Poisson Process are constant in size. Each refugee unit produced by the Poisson Process is of equal size and is therefore consistent in its interactions with military units defined in the wargame.

The rate for a community spinning off refugee units varies inversely with the level of well-being for a community. Decreasing the level of well-being in a community over a period time increases the rate of refugee units created during that period of time. Therefore, the rate for the Poisson Process must also vary inversely with the level of well-being for a community, making the process a non-homogeneous Poisson Process.

Using the Poisson Process to create refugee units has several serious limitations. This method does not account for a panic effect common in behavior of groups or communities of people. Civilians show a risk taking behavior when the level of well-being is low for a community. Civilians are more sensitive to what other civilians in the community are doing when the level of well-being is low. Once a person decides to leave, other people are more likely to follow, fearing that they may not know something that the person leaving does know. Given this effect, the model could significantly underestimate the number of

refugees that should be generated during periods of low well-being. Civilians are also risk averse to leave their community during periods when the level of well-being is high. Using the Poisson Process, also does not allow any flexibility in the size of refugee units created. A consistency of events is assumed by the Poisson Process that requires the unit size to be fixed for each refugee unit created. This method also fails to consider the size of the community from which the refugee units spring. Using a Poisson Process, a community of two million with the same level of well being as a community of two thousand both produce a unit of refugees at the same time. It is not reasonable for a community of two million to produce the same number of refugees as a community of two thousand, thus, the number of refugees produced must also depend upon the size of the community producing the refugees.

2. Creation of Dislocated Civilians (Graphical Model)

When a refugee unit is created depends on the level of well-being in the community which is the progenitor for the refugee unit. When the community can no longer provide adequate services for its membership, a number of civilians waive their association to a community to seek out other communities capable of providing necessary goods and services to its members. As the level of well-being drops within a community, dislocated civilians are formed. A model therefore must produce a refugee unit when the level of well-being falls in a community.

The size or number of dislocated civilians contained in a refugee unit also depends on the level of well-being for the community generating dislocated civilians. A community with a very low level of well-being produces more dislocated civilians than a community that only has a moderate level of well-being. As the level of well-being falls in a community, the size of a refugee unit created increases. The number of dislocated civilians in a refugee unit also depends on the size of the community from which the refugee unit springs. Two communities, one with a population of ten thousand civilians, another with a

population of two million, do not produce the same number of refugees given same level of well-being. The expected outcome in a realistic scenario requires the larger community to produce more dislocated civilians. Members of a community also perceive leaving the community to become dislocated civilians as a risky venture. Civilians in a community are risk averse to becoming dislocated civilians at high levels of well-being. When the level of well-being is very low, however, the more risky venture is staying in the community. At low levels of well-being, civilians are risk takers willing to leave the community, since there is little to loose. Historically refugee problems do not linearly build to a crisis, rather building slowly in numbers until a flood of dislocated civilians suddenly occurs when a critical point is reached in the society. The number of refugees generated should be very sensitive to change as the critical point in well-being is approached. Figure 11 illustrates a function that can model this expected behavior. The response curve between well-being and refugee unit size in Figure 11 was generated using equation 17 for a notional community with a population of ten thousand people. In equation 17 the population of the community is defined as c , and the level of well-being for the community is defined as w . The critical point in this function occurs near a level of well-being

$$R(w, c) = \begin{cases} \left(\left(\frac{(w - 0.5)}{4} \right)^{0.33} + 0.5 \right) (c) & \text{for } w > 0.5 \\ 0.5 - \left(\left(\frac{(w - 0.5)}{4} \right)^{0.33} \right) (c) & \text{for } w \leq 0.5 \end{cases} \quad (17)$$

of 0.50. The change in the number of dislocated civilians contained in a refugee unit created near this critical point can be large and models how a flood of dislocated civilians can suddenly occur with a decrease in the level of well-being for a community.

An advantage to using this function is that it can be tuned to fit the situation. The function can be modified to produce a more risk averse curve by increasing the value of the exponent. Also, the position of the curve can be

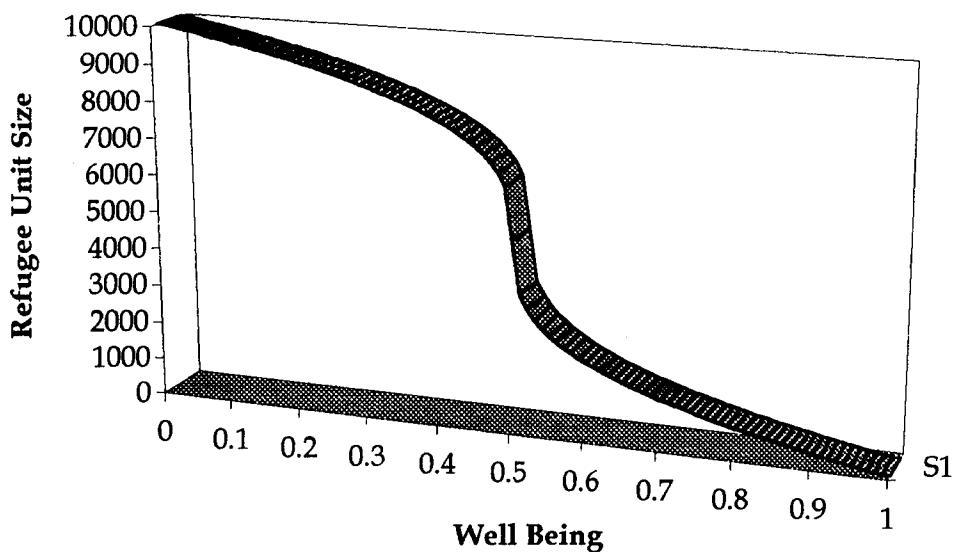


Figure 11. Expected Behavior in Generating Refugees

adjusted by varying the value of the constants from their value of 0.5. Although the curve in Figure 11 shows the characteristics expected to produce refugees, it is not reasonable to believe even in a community with zero well-being that everyone would leave. A community does not disappear in an instant. Ghost towns occur, but they require more than a day to emerge. A more realistic curve must lower the number of refugees produced at very low levels of well-being. Civilians are also more risk averse at high levels of well-being because they have more to lose, and are risk takers at low levels of well-being to get essential needs. Civilians are very hesitant to leave their community at high levels of well-being. This risk averse behavior is validated by the existence in communities of street people who have no means of food and shelter. However,

after some inertia is overcome, people slowly begin to leave followed by a rush of people leaving if the level of well-being remains low. The expected response curve should be flatter for the risk averse portion of the curve than in the risk taking portion of the curve. This behavior is similar to the mass movement of people to California from the Midwest dustbowls during the droughts and economic depression of the 1930s. Initially the number of people going west was small. The numbers suddenly increased dramatically as the critical point in well-being was reached in the society.

Equation 17 is modified to reflect a higher degree of risk aversion for communities with higher levels of well-being, increase the risk taking at lower levels of well-being, and to decrease the maximum number of refugees that can be formed at a given time. Equation 18 gives this modified representation of how dislocated civilians in refugee units are created as a function of well-being. The behavior of equation 18 is illustrated for a notional community with a population of ten thousand in Figure 12. The graphical model provides a realistic representation of how dislocated civilians are formed. However, this model also allows for adjustments which may be peculiar to a specific population or as the result of further study.

$$R(w, c) = \begin{cases} \left(\left(\frac{(w - 0.5)}{4} \right)^{0.28} + 0.2 \right) (c) & \text{for } w > 0.5 \\ \left(0.3 - \left(\frac{(w - 0.5)}{4} \right)^{0.35} \right) (c) & \text{for } w \leq 0.5 \end{cases} \quad (18)$$

3. Dislocated Civilians (Differential Method)

Investigation of the dislocated civilian process included modeling the creation of refugees in a manner similar to the square law Lanchester attrition equations shown in equations 19 and 20. Equation 19 relates the size of X to the

size of Y and Y's ability to cause casualties to X. Similarly equation 20 relates the size of Y to the size of X and X's ability to cause casualties to Y. Many hunter/predator relationships such as the spread of epidemics and

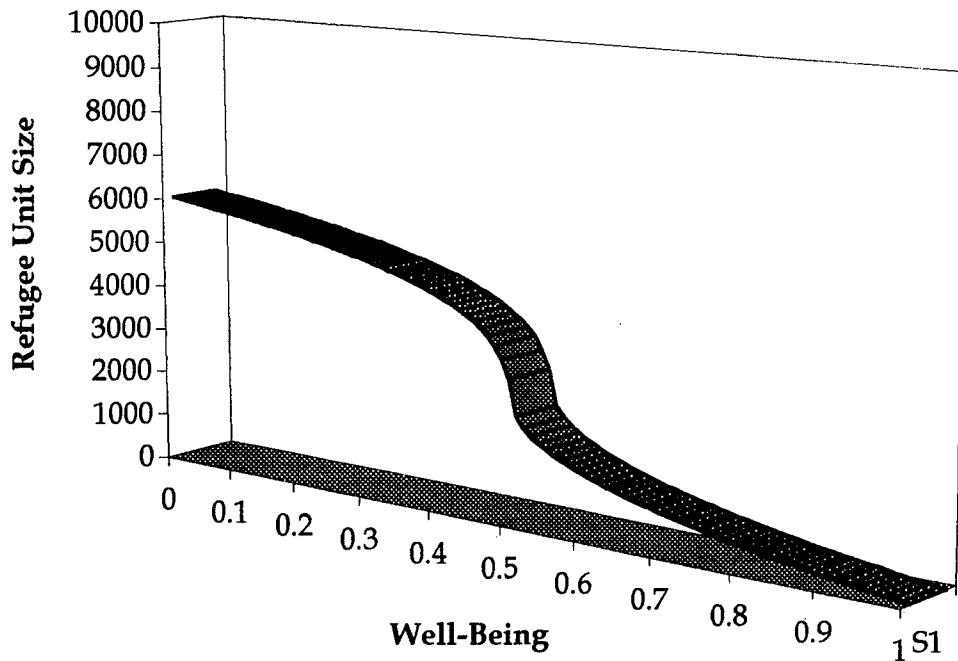


Figure 12. Refugees Generated as a Function of Well Being

$$\frac{dX}{dt} = -\alpha Y \quad (19)$$

$$\frac{dY}{dt} = -\beta X \quad (20)$$

rumors have been modeled by applying adaptations of Lanchester's equations. [Ref. 14:p. 302] The problem of determining the size of refugee units has a structure similar to these adaptations of Lanchester's equations. The change in size of refugee units depends on the level of well-being in the progenitor community and the size of this parent community. Similarly the change in size

of a community depends on the change in its level of well-being and the size the refugee unit. These relationships are summarized in equations 21 and 22. To increase the number of dislocated civilians in a refugee unit the level of

$$\Delta R = -C(\Delta \text{well-being}) \quad (21)$$

$$\Delta C = R(\Delta \text{well-being}) \quad (22)$$

well-being must decrease. The negative number from this decrease is offset by the negative sign in equation 21, as a result increasing ΔR . Equations 21 and 22 are rewritten as equations 23 and 24 in the same form as the Lanchester equations. In the same manner that force sizes as function of time can be derived from Lanchester equations, force sizes as a function of well-being can be derived from equations 23 and 24. [Ref. 16 : p. 66] In order to get an equation that

$$\frac{dR}{dw} = -C \quad (23)$$

$$\frac{dC}{dw} = R \quad (24)$$

is written only in terms of R , the derivative of equation 23 is taken with respect to well-being yielding equation 25. By replacing the right side of equation 25 with R as defined in equation 24 and moving the term to the left side,

$$\left(\frac{d^2R}{dw^2} \right) = -\frac{dC}{dw} \quad (25)$$

equation 25 is rewritten as equation 26. This is a second order homogeneous differential equation that can be solved in closed form. The general form of the solution is given in equation 27. Several initial conditions are known. When the

$$\frac{d^2R}{dw^2} + R = 0 \quad (26)$$

$$R(w) = c_1 e^w + c_2 e^{-w} \quad (27)$$

level of well-being for a community is zero, a large number of dislocated civilians are generated. This large number of dislocated civilians is defined as c_0 . This initial condition is summarized by equation 28. When the level of well-

$$R(0) = c_0 = c_1 e^0 + c_2 e^0 = c_1 + c_2 \quad (28)$$

being is 1.0 no dislocated civilians are generated. The initial condition for a level of well-being of zero is summarized by equation 29. Using equations 28 and 29

$$R(1) = 0 = c_1 e^1 + c_2 e^{-1} = 2.718c_1 + 0.316c_2 \quad (29)$$

to solve for the constants, c_1 and c_2 , gives equations 30 and 31. In equation 32 the constants are replaced with the right side of equations 30 and 31 giving a specific

$$c_1 = \left(\frac{-0.368}{2.35} \right) c_0 = (-0.1566)c_0 \quad (30)$$

$$c_2 = \left(\frac{2.718}{2.35} \right) c_0 = (1.1566)c_0 \quad (31)$$

solution to equation 26. The term c_0 , which is the number of dislocated civilians formed at zero well-being for a community is some fraction of the community's size. For Figure 13 the maximum number of dislocated civilians that are formed

$$R(w, c) = (-0.1566)(c)(e^w) + (1.1566)(c)(e^{-w}) \quad (32)$$

at a given time is defined as the population of the community. Figure 13 illustrates for a notional community with a population of ten thousand the size of a refugee unit as a function of the community's well-being. The size predicted by the model is compared to a linear response. A small amount of risk averse

behavior is illustrated throughout the range of well-being. To implement a risk taking behavior for a level of well-being below 0.5 equation 32 is modified by

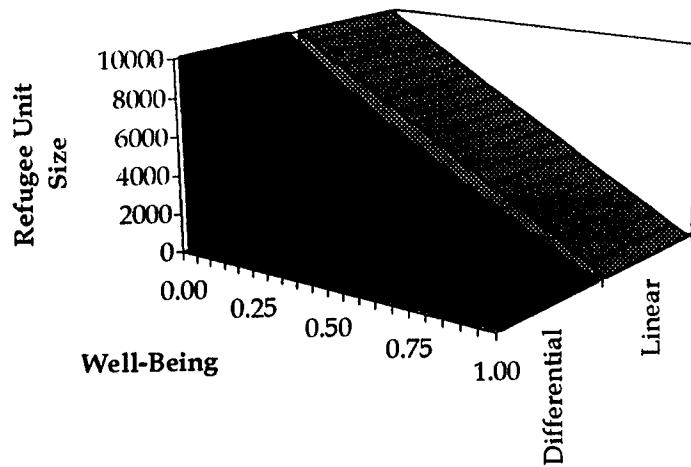


Figure 13. Refugee Unit Size as a Function of Well-Being

taking the square root of the well-being. To implement a larger degree of risk aversion for well-being of 0.5 and above, equation 32 is modified by squaring the well-being term. If the maximum number of refugees that is generated for a community at a given time is six tenths of the community's size, c_0 is redefined as $(0.6)c$. For larger communities the transportation network may not accommodate the entire population exiting a community during one day. The larger the town the smaller the fraction is that can depart in one day. This change in c_0 is reflected in equation 33. If the road network for the notional

$$R(w, c) = \begin{cases} (-0.1566)(0.6c)(e^{\sqrt{w}}) + (1.1566)(0.6c)(e^{-\sqrt{w}}) & \text{for } w < 0.5 \\ (-0.1566)(0.6c)(e^{w^2}) + (1.1566)(0.6c)(e^{-w^2}) & \text{for } w \geq 0.5 \end{cases} \quad (33)$$

community of ten thousand used earlier in the graphical model can only accommodate six tenths of the population, c_0 is lowered to a value of 6000. The number of dislocated civilians in a refugee unit generated from equation 33 for

the notional community of ten thousand considered earlier in the graphical model is illustrated in Figure 14.

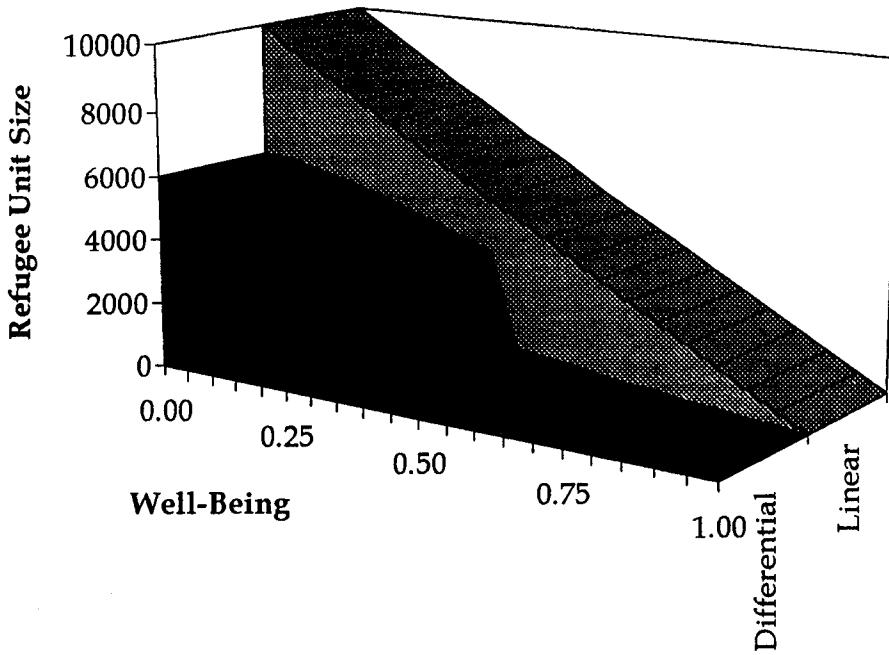


Figure 14. Implementation of Risk Aversion and Risk Taking Behavior

Both the graphical model and the differential model allow tuning of the equations. A comparison of the behavior generated by the graphical model and the differential model in Figure 15 shows that the two models can be brought into close agreement. The graphical method shows a smoother transition from the risk averse behavior to the risk taking behavior near the critical point. Since the change is so abrupt near the critical point in the differential model, the graphical model may be more desirable. The graphical model still represents the flood of refugees that occurs near the critical point. The differential model may not enable players to perceive that the critical point is near for civilian units because the change is too abrupt. The differential model, however, validates the results predicted by the graphical model. The close correlation of the two models as shown in Figure 15 substantiates the logic used to construct the graphical model.

4. Behavior of Refugee Units

Once refugee units are created, a rate of movement and direction of travel must be determined. The mobility rate of the a refugee unit will vary based upon the availability of transportation assets within the unit. A rate of two kilometers per hour was suggested by CPT Yee. [Ref. 9:p. 91] Depending on the

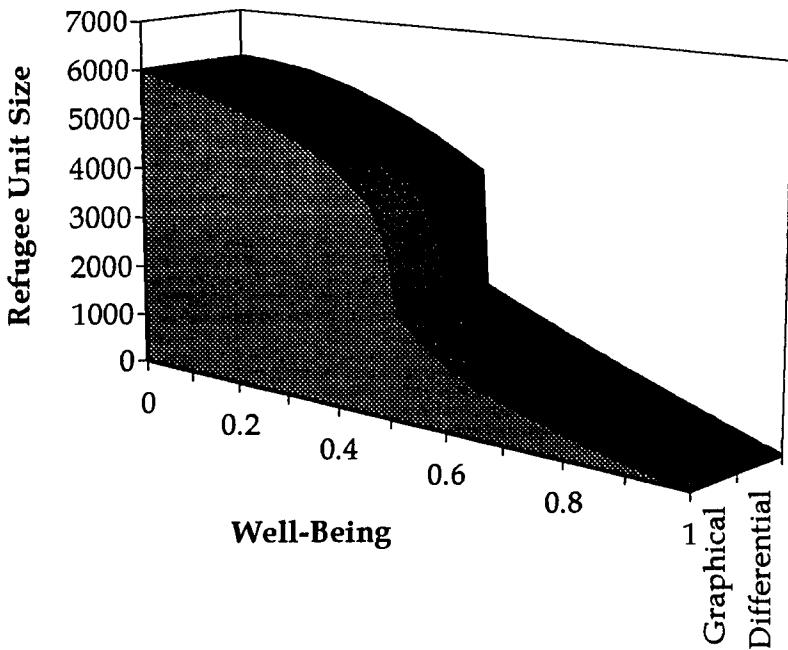


Figure 15. Comparison of Graphical Method with Differential Method

region of the globe considered, civilians may have assets such as cars, trucks and buses. An assumption is made that these assets will have been sold or traded in exchange for food and shelter prior to citizens being forced into a dislocated civilian status. The destination or direction of travel for a refugee unit is prioritized below.

1. Away from any perceived conflict. The knowledge of where the conflict is assumed to be ground truth.
2. Toward units of a side for which the Side Relationship of JTLS is "friend".

3. Toward the nearest community which has a higher level of well-being.

The knowledge of other communities' level of well-being is assumed to be ground truth.

4. Toward a Collection Site established for dislocated civilians.

Knowledge of the location of this site is assumed to be free information which is freely spread throughout the battlefield.

5. A random direction, lost and wandering on the battlefield.

The direction is determined by applying these rules in order. If multiple possibilities exist, Monte Carlo techniques are used to determine the destination.

The route selected for this destination will take advantage of the road network, since dislocated civilians prefer to travel on the road network.

Ideally refugees also collect short term information during their movements on the battlefield. For refugee units collected at a marshaling point, this information is made available to military units once the refugee unit has reached the collection point. The refugee unit acts as a sensor for the military units of the side collecting the dislocated civilians. This is modeled using the same methodology that is used for HUMINT teams. [Ref. 13:p. 3-71]

Information gathered from HUMINT teams in JTLS depends on three factors. These three factors are the area covered of the HUMINT team, the probability of detection, and the amount of time the gathered information is delayed. The area covered is the narrow area traversed by the refugee unit. The probability of detection is smaller than the probability of detection associated with military HUMINT teams. The probability of detection is smaller because dislocated civilians:

- are not trained to gather intelligence.
- are giving information based only on their recollections of information available during their transit.
- the variability of the information provided by a group of civilians is large. Many versions of what was seen will be contradictory.

- are not equipped to gather information.
- are not focused on gathering information.

The gathered information is delayed until the refugee unit is assimilated into a collection point.

The refugee units created eventually are:

- assimilated back into a community
- destroyed by starvation
- merge with other refugee units
- destroyed by military units.

This process is similar to a pin ball game in which the ball, which can be thought of as the refugee unit, rolling around the battlefield bumping up against combatant units, other refugee units, and communities. Ultimately the refugee unit will either be destroyed by starvation, from attrition from exposure to combat as the result of moving around the battlefield, or be absorbed into some other community. The refugee unit will bounce around the battlefield creating civil-military interactions for all sides in the conflict until absorbed.

The model presupposes that civilians will not remain in a community and starve. It assumes that civilians will strike out as refugees or dislocated civilians in search of food and shelter before dying as a result of starvation. When a refugee unit is created, it is assumed it departs with two days worth of food. This is how much foodstuffs can reasonably be carried in the absence of transportation assets. This value was also proposed by CPT Yee. [Ref. 9:p. 91] When the *foh* is zero the refugee unit begins to be reduced by starvation. This is modeled essentially by attrition methods existing for weapon systems using a probability of hit equal to 1 and a probability of kill equal to 0.2. A forage capability provides a small quantity of foodstuffs to refugee units as they move through crop producing hexes. The small supplement of foodstuffs from forage enhances the model without dominating the model.

Refugees can be assimilated into other communities in one of three ways. They can arrive at a community with a higher level of well-being than the refugee unit. This creates a situation where refugee units may move from community to community being absorbed, lowering the community's level of well-being enough to generate a new refugee unit. This scenario represents how refugees may, in fact, move from community to community without becoming a permanent part of the communities. The net effect is to lower each community's level of well-being unless an ideal end state is reached where enough essential commodities are on hand for the total civilian population in a theater. When two refugee units meet on the battlefield, they may merge, in order achieve a higher level of well-being than by staying separate. Refugees may also be collected into a camp at a collection point for dislocated civilians.

5. Military Interactions with Refugees

Trafficability for military units moving through hexes containing refugee units can be affected by using methods already existing in JTLS. Identification and detection of refugee units can also use existing methods.

Players may task military units to collect refugee units from the battlefield. Military units may also be tasked to move communities. This type of mission is considered in the section Noncombatant Evacuation (NEO). Collection of refugees from the battlefield is conducted after their presence is detected by a side's sensors and the refugee unit has been identified. The mission is tasked to a military unit through player input in the form of a *Collect Dislocated Civilians* tasking order. CPT Yee discussed tasking orders in depth and a version of the interface proposed by CPT Yee can be implemented. [Ref. 9:p. 60] Minimum information required for the *Collect Dislocated Civilians* tasking order should include:

- Military unit tasked to collect dislocated civilians.
- Perceived location of civilian unit.
- Start no later than time to begin movement to the civilian unit.

- Destination of collected dislocated civilians.
- Period of time to conduct operation.

Refugees may also intentionally arrive at a designated refugee collection point, which is portrayed simply as a military unit tasked with collection of refugees stationed at a designated location. From collection points, refugee units are assimilated into a stationary community (camp). Maintaining the level of well-being for camps is the responsibility of the military.

B. NONCOMBATANT EVACUATION (NEO)

This operation requires players to direct military units through a *Conduct NEO* tasking order to move to a location where a player believes a civilian unit is located. The tasking order also contains the following information:

- Military unit tasked to collect dislocated civilians.
- Location to be evacuated.
- Specific civilian units to be evacuated (default is all).
- Start no later than time to begin movement to the civilian unit
- Destination of civilian unit.
- Period of time to conduct evacuation.

The civilian unit, during the evacuation, becomes completely dependent upon the military unit. Players need to ensure the level of food and shelter is transferred to the civilian unit, since adequate food and shelter must be provided to the civilian unit in an attempt to maintain a sufficient level of well-being for the civilian unit. By maintaining or improving the level of well-being in the civilian unit during the evacuation the number of refugee units formed is minimized.

The tasked military unit must also have transportation assets to move the civilian unit. The time required to complete the move is dependent upon the transportation assets available in the tasked military unit. The time to complete the move can be calculated using the same methods that are used to calculate

time to complete delivery of supplies to military units. The time to complete the evacuation is also assumed to be reduced by (0.9)(time to evacuate) if a CA unit is integrated into the task organization of the unit conducting the NEO. The expertise of a CA unit in local language, culture and customs reduces the communication barrier between the civilians and military facilitating a more efficient and faster evacuation.

The destination of the civilian unit may be a camp community maintained by the military with food and shelter. An example of this type scenario would be relocating Haitian and Cuban refugees to camps such as the Naval facility at Guantanamo Bay. The destination may also be an existing community. The level of well-being for the destination community could be significantly affected depending on the size of the civilian unit being relocated. If the community cannot sustain this population growth, refugee units are formed. Players are forced to evaluate not only the evacuation of a civilian unit, but the consequences of the movement.

C. FOREIGN NATION SUPPORT (FNS)

The civil-military interaction where the military receives logistical support from the civilian community has been an important element of the NATO planning for the defense of Europe for many years. In NATO a wide range of services, to include augmentation of transportation assets, construction of defensive positions, maintenance and storage of material in POMCUS sites, were all negotiated and arranged prior to hostilities with the local community government. Because of this, when the term Host Nation or Foreign Nation Support is used, the civil-military interaction that occurred in NATO is what comes to mind. Recent experiences, however, have shown that predicting where the next conflict will occur is extremely difficult. A more realistic scenario will require the military to arrange for Foreign Nation Support during the deployment or after hostilities have begun. Therefore, this process needs to be

modeled as tasks that staffs are performing in theater instead of existing arrangements already in place.

Foreign Nation Support can be divided into two categories. Third Party Support (TPS) is provided by nations not necessarily in a theater of operations. This can easily be modeled as a strategic resupply of materials coming into theater. For TPS, the materials are added to an Echelon Above Corps (EAC) unit's stock as a Login event when the supplies are programmed to arrive in theater. The second category is Host Nation Support (HNS) which is provided by the nation hosting the presence of the military forces. HNS, by its nature, is a more decentralized process used to support individual military units. This requires that the HNS process be modeled with sufficient detail to interact with individual military units. HNS is the model further developed in this section for inclusion into current wargames and simulations.

HNS acts as a supplement to the military's logistic system. During the early stages of the military's deployment to a theater of operations, or for military units with a sparse logistics infrastructure, HNS may be the major segment of the logistics structure in place for a military force. HNS can also be used as a logistics boost for a theater of operations with a developed logistics infrastructure. Examples of the augmentation HNS can provide are sources of additional food and fuel, increasing available transportation assets, or supplementing maintenance operations. For this model HNS is categorized into two areas.

- Augmentation of supply items, such as food and fuel.
- Augmentation of services, such as maintenance, engineer and medical support.

1. Augmentation of Supply

Similar to military support units, civilian units can act as a supporting units for military units. Modeling HNS for supply items can use much of the existing logistic structure found in current wargames. JTLS already allows

military units to use dock facilities and beddown facilities. What needs to be added is a means of allowing civilian units to interface with the military units. The civil-military interface is distinct from the support relationship between military units and their assigned support units. Unlike military support units, civilian units have the option to decline requests for support from the military. Current wargames need to add the interface between military and civilian units to provide the information to model the negotiation and decision phase during the contracting for HNS from a community. Once the community has agreed to support a request for HNS, the existing logistics methods within current wargames can be extended to civilian community units. This section focuses on modeling the interface between civilian and military units and the processing period which consists of two phases:

- The negotiation phase; the time required to negotiate with the community to get a commitment from the community to either to support or reject the request for HNS.
- The decision phase, determine whether the community will support the request.

When a player determines that a request for HNS needs to be generated to support a military unit, information must be provided to the community through an interface specific for HNS. The *Request for HNS* is similar to the tasking order which enables players to interface with military units. The *Request for HNS (Supplies)* must contain the following information:

- What supplies are requested?
- What is the quantity requested?
- Is the requesting military unit to negotiate and coordinate the HNS, or which CA unit is tasked to negotiate the HNS agreement?
- From which civilian unit is HNS requested?

2. Augmentation of Services

The augmentation of services can also use much of the methodology utilized in current wargames and simulations. Again, an interface is needed to provide the information necessary from the players to model the decision negotiation phase of requesting HNS. The following information is needed for the *Request HNS (Services)* interface:

- What services are requested?
- For what period of time are the services needed?
- Is the military unit to negotiate and coordinate the HNS, or which CA unit is tasked to negotiate the support agreement?
- From which civilian unit is HNS requested?

It is necessary for the player to identify in the request for HNS if the requesting military unit will manage the negotiations for the HNS requested, or is a CA unit tasked to negotiate the request. The time required for a CA unit to negotiate the HNS request is shorter because of its expertise in dealing with civilians, knowledge of the language, and familiarity with the local customs and culture. However, a military unit may also attempt to effect the negotiation on its own. The time required to complete this phase for a military unit acting without the assistance of a CA unit is longer. The player inputting the request for HNS will have to evaluate and decide which option to select. The optimal policy will depend upon the number of current requests the CA unit is working.

3. Queuing Model for Negotiation

The system can be modeled using a queuing model. The amount of time required to negotiate the HNS between the civilian unit and the military unit can be modeled using a two server queue as illustrated in Figure 16. The service time for each server represents the time to negotiate the agreement. In general the requests will be fairly easy to decide upon and a large number of the decisions will be very quickly made by the community. However, some

decisions could take a long time to be completed. This supports using the Exponential Distribution to describe the service times of both servers. The following assumptions are made for the queuing model:

- The service times for requests for HNS are assumed to be from an Exponential Distribution.
- HNS requests are processed using a first-in-first-out (FIFO) mechanism.

The shape of the Exponential Distribution for the two servers is different. The mean time to complete the negotiation process using the CA server is shorter than the service time of choosing the server that represents a military unit doing

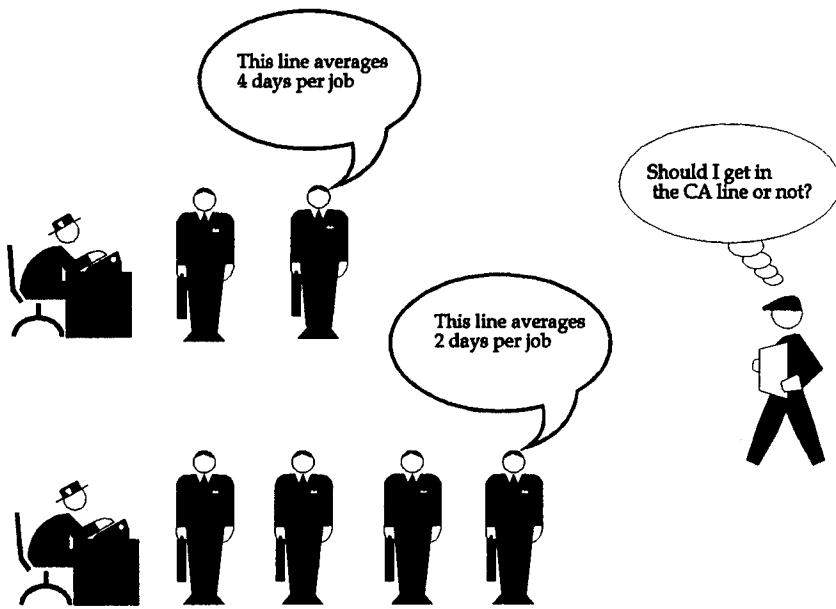


Figure 16. Queuing Process for HNS Agreements

its own negotiation. On average the service time is shorter if a CA unit is chosen to negotiate the HNS agreement. The total time in the process may still make the player's optimal decision to select the option of using the military unit to conduct its own negotiation. If the CA unit has a significant queue waiting for the server, the time spent waiting for the server may exceed the penalty of the longer service time for the military unit conducting its own negotiation. It is the

player's choice in the input interface which option is selected. The option that is selected does not effect whether a community will support or refuse the request for HNS, only how long it takes to get a decision from the community.

4. Decision Criteria

The decision phase is modeled in the following manner. First, a determination must be made if the supplies requested are critical items. Critical items are those supplies that are absolutely essential to a community. These supplies are the same items used to calculate the level of well-being in Chapter III. For critical items, if the request for support will lower the current level of well-being to less than 0.95, the request for support is rejected. If the request for supplies are for non-critical items, the request is approved if the request does not lower the community's stockage level below its stockage reorder level. The stockage reorder level can be thought of as the basic load necessary for a community's ongoing operations. For services the same logic applies with the additional constraint that both the civilian unit and the military unit occupy the same hex.

Methods already exist in current wargames and simulations to model the actual transfer of supplies from one military unit to another. Factors such as time required to ship items, attrition enroute, and scheduled delivery date can all use these existing methods in military-to-military unit support. These methods can be extended to cover civilian units acting as supporting units for military units. Augmentation of services from civilian units can also use existing methods. As an example, times to return to service can be shortened for equipment if civilian service augmentation is provided to a military unit.

This method is chosen because it will integrate easily with the existing architecture of current wargames and simulations. JTLS, as an example, already uses a basic load field in the Sustainment Logistics Prototype as an index to reference when supplies need to be reordered to prevent unit performance from being degraded. Further work in the decision phase could increase the

sensitivity and realism provided by this model. Supply items other than foodstuffs could be classified as critical supply items for communities and this may increase the sensitivity of this method.

D. MILITARY CIVIL ACTION

Military Civil Action (MCA) is modeled as an attempt by a side to improve a civilian unit's level of well-being. As an example, this can be achieved by committing an engineer unit to repair housing destroyed in a community. After the project is completed the level of well-being increases in the civilian unit. MCA is oriented toward improving a population's standard of living. Players use a *Repair Facilities* tasking order to initiate this mission. The following information needs to be included in a *Repair Facilities* tasking order:

- Military unit tasked to repair dwellings.
- The player's perceived location of the civilian unit.
- The number of shelters the tasked unit should repair.
- Time the tasked unit should begin repairing shelters (default is upon arrival).
- Completion time (if less than calculated completion time).

Conducting extensive MCA creates goodwill and better understanding between the civilian units and the military units of a side in the wargame. Improving the understanding between the military units of a particular side and civilian units reduces the average time required to negotiate agreements in FNS for both CA units and military units. This better understanding between civilians and a side also enables a larger portion of intelligence gathered by the civilian side to be shared with the military side conducting MCA. The time required to complete the project can use methods similar to those used to determine time to repair other objects in JTLS such as runways. The capability of the military to improve the level of well-being for a community has to be balanced by the player with the priorities for employing the engineer assets in support of military units.

E. POPULACE AND RESOURCES CONTROL

Resource control involves denying resources to the enemy. This includes denying the enemy access to information from foreign nation sources, and improving intelligence from host nation sources on the enemy's disposition.

[Ref. 17:p. 3-8] Examples of this process include destroying supplies in a community that the enemy could use as it advances. Another example is providing these supplies to a community as the enemy withdraws. This process is an exercise for the game player to balance influencing the level of well-being for a community with his particular military objectives. Improving the level of well-being enhances a player's side capabilities in HNS and intelligence. Destroying supplies such as foodstuffs lowers the level of well-being in a community, if the population has not been evacuated. The methods used to model these activities involve adjusting the level of supplies within a civilian unit.

Players create a *Destroy Supplies* tasking order, *Confiscate Supplies* tasking order, or *Conduct Resupply* tasking order to initiate missions. Players must provide the following specific information in the *Destroy Supplies* tasking order:

- The location of the civilian unit targeted.
- What military unit is to move to civilian unit.
- When the military unit should begin movement.
- What supplies are to be destroyed.
- The start time to begin destroying supplies.
- The “no later than” completion time for destroying supplies.

The time required to destroy supplies is assumed to be exponential since the number of soldiers destroying supplies is fixed and as the amount of supplies increases, the ability to destroy supplies is degraded by manpower issues such as location, collection, and destruction of the items.

The tasking order *Conduct Resupply* to provide supplies to civilian unit contains similar information as follows:

- The perceived location of the civilian unit to be resupplied.
- What military unit is to move to the location.
- The start time for military unit to begin movement toward the civilian unit.
- What supplies to provide.
- What quantity of each type of supply item is to be transferred.

Players must ensure that units tasked to conduct resupply of civilian units have necessary supplies on-hand for the resupply, and the logistics support for these military units can support the increased flow of transferred supplies.

F. OPERATIONS OTHER THAN WAR (OOTW)

Many OOTW can be represented using the tasking orders developed in the previous sections. Several OOTW are discussed. An example is the conduct of humanitarian relief operations. Humanitarian relief operations can be modeled using the *Conduct Resupply* tasking order discussed in Section E, POPULATION AND RESOURCES CONTROL. Humanitarian relief operations primarily involve providing disaster relief supplies, such as foodstuffs and shelter, in the form of tents. Humanitarian relief operations also include repairing damaged facilities such as homes or shelters. Engineer assets can be employed to repair communities using the tasking order *Repair Facilities* discussed in the Section D, MILITARY CIVIC ACTION.

Peacekeeping operations can be modeled by taking advantage of JTLS's multi-sided capability by employing three military sides and a civilian side. The third military side (peacekeepers) mission is to reduce the military conflicts between the two warring military sides and ensure the level of well-being for communities is supported. The peacekeepers separate the two warring sides with the neutral peacekeeping units preventing units of the two warring sides from attaining a conflict status in the wargame. Assisting NGOs in collecting dislocated civilians involves the tasking order *Collect Dislocated Civilians*,

providing relief supplies using the tasking order *Conduct Resupply* and repairing housing by using the tasking order *Repair Facilities*.

V. CONCLUSIONS AND RECOMMENDATIONS

The objective of this study is to provide a proof of principle that civilians and their interactions with the military can be modeled and integrated into a currently fielded theater level model. Figure 17 provides an overview of the method developed in this study. A variety of tools were used in this study to include networks, Dijkstra's algorithm, differential equations, queues, risk taking and risk averse behaviors. These tools are used to model a wide range of civil-military interactions, including some aspects of civil affairs, a limited degree of Psychological Operations and some Operations Other Than War. This study is not intended to be definitive for these three areas, rather it develops a methodology expanding the environment portrayed in current simulations and wargames. The emerging importance of interactions between the military and civilians is a fundamental ingredient in the post cold war environment. The methodology presented in this study can be extended in each of these three areas to encompass additional interactions between the military and civilians.

A. CONCLUSIONS

Civilian units cannot be evaluated using the same measures of performance as military units. The measures of performance such as rate of advance, probability of kill, and personnel strength do not provide insights into the behavior for a group or unit of civilians. Defining the abstract notion of a unit's well-being enables predicting when specific behaviors are expected to occur. The well-being function defined in this study, although crude in that it considers only a few factors such as food, shelter and distance to conflict, nevertheless enhances the representation of the environment within which military units are currently required to operate. The well-being function for a community depends primarily on the current situation, but also incorporates a perception of the future, based upon some information about the future and past performance of the community.

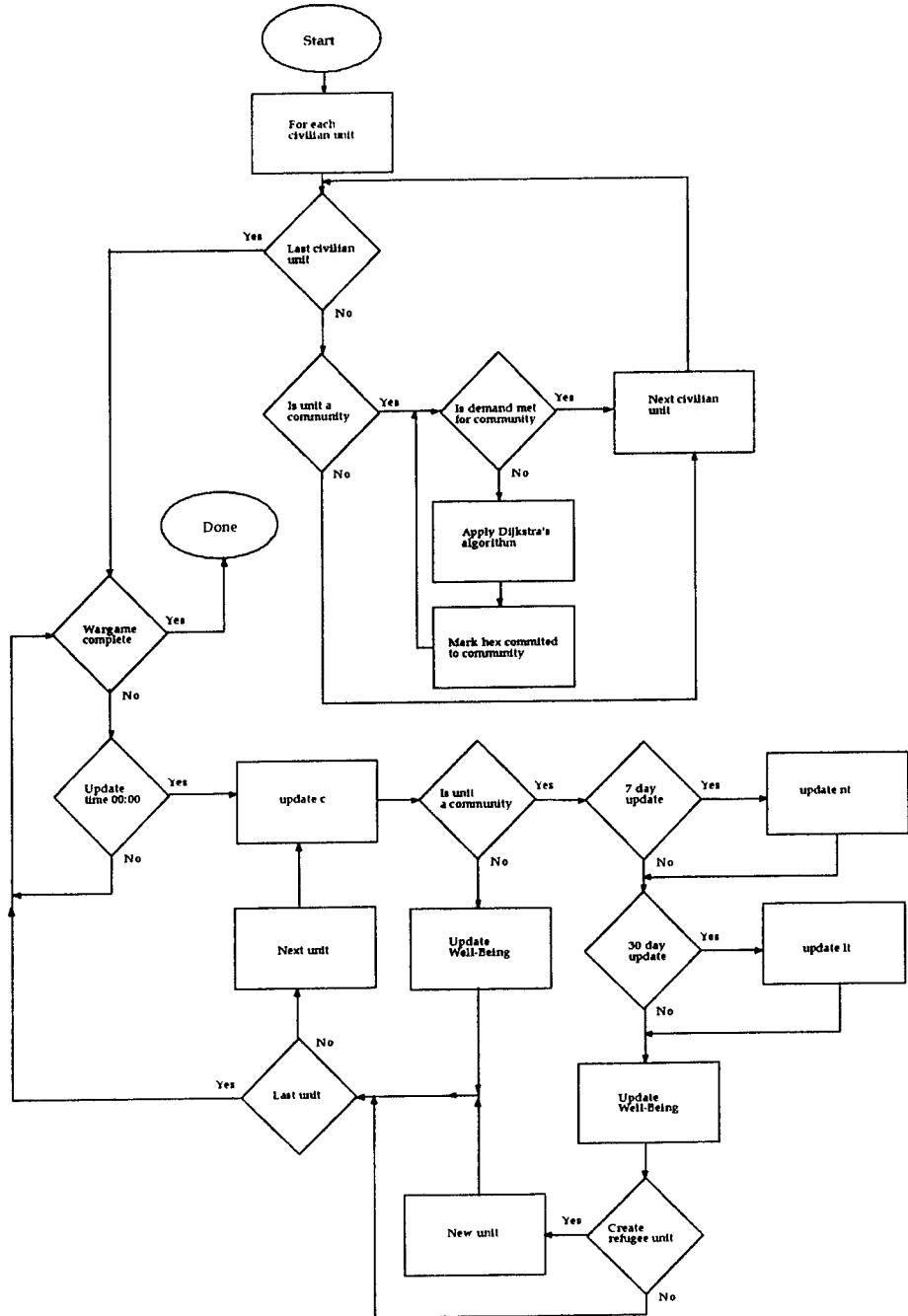


Figure 17. Overview of Methodology

The civil-military interactions considered result from two types of action-reaction scenarios. The first possibility involves a civilian unit creating an event to which players controlling military units may react. This study only develops one interaction, the generation of dislocated civilians, that fits in this category. Other events that could be developed in the future include rioting and starvation. The second possibility allows players to proceed, actively performing actions which directly or indirectly impact on civilian units creating an event as a reaction. The remaining interactions modeled in this study fall under this category. This study proposes several tasking orders for inclusion into JTLS, enabling players to react to events or interact with civilian units. The intent in the development of this methodology is to maximize the use of methods already existing in JTLS and extending their interaction with civilian units.

This model was developed as a training aid for joint commanders and their staffs. The relationships in this study between civilian behaviors and well-being are approximations based upon expected behaviors. The lack of data to quantify behaviors such as generation of dislocated civilians as a function of well-being prevents this model from being used as an analytical tool. However, this study has concentrated on developing methodologies that can be further refined as this subject area matures. This study also develops a foundation which future studies can use to frame questions and data requirements to quantify these relationships.

B. FURTHER WORK

This study is an initial attempt to model civilians and the soft factors of civil-military interactions. The methodology of this study should be integrated into a developmental version of JTLS for testing and evaluation. Further work on the methodology should include expanding the level of definition of the well-being function to include accumulation of wealth for civilian units. The

distribution of this wealth within the community may also effect the degree of importance or weight this variable exerts in the well-being function. Including accumulation of wealth as a variable permits modeling civilians in a low intensity conflict environment and during the political periods immediately preceding and following a conflict. Another aspect of the well-being function that should be considered is medical. Threats of epidemics and sickness are significant variables that affect the behaviors of groups of civilians. Another issue that can affect the level of well-being is political safety. When groups in a society are targeted, the level of well-being must go down for the targeted group. A recent case of this phenomenon is in Rwanda where members of the Hutu tribe fled in fear of reprisals from the Tutsi tribe. The current weights for each component of the well-being function are only starting points that lead to an expected behavior and should be the focus of further studies.

The nature of civilians is not adequately described by the current object structure of JTLS. The current architecture of objects in JTLS is derived from the Battlefield Operating Systems (BOSs). U.S. Army doctrine developed these BOSs to synchronize battle effects in time and space. [Ref. 12:p. 2-12] The BOSs are a collection of battlefield factors that are manipulated to achieve maximum combat power and are only a subset of characteristics that describe a group of people, soldiers. To completely model the environment, other Civilian Operating Systems (COS) need to be included. Possible COS to be considered include:

- Economic Systems
- Religious Orientation
- Ethnic Background
- Political Systems

Implementation of the COSs greatly simplifies the modeling of civilians and their interactions with the military. The COSs provide a base of data that is used to better assess measures of performance for civilian units and the effect of

interactions between the military and the civilian presence in a theater of operations.

The Economic Systems functional prototype is similar in nature to the Combat Systems prototype for military units and defines the capabilities for a civilian faction. The Economic Systems prototype enumerates whether a faction can have farms, banks, oil refineries, etc., in its economic base. Religious Orientation is used to define factions that may be distinct due to religious preference and does not have to distinguish a faction. However, many communities are composed and distinguished by a common religious preference. Several examples include the polarization of communities between the Serbs and Muslims in the former Yugoslavia, and the Palestinian communities in the West Bank distinct from Jewish communities. Some communities may be composed of factions. A community could be represented by two civilian units of different factions. For example, in Beirut during the 1980's, the city was divided by "the green line." where Christians were separated from Muslims. The Political System prototype defines the freedoms enjoyed by a particular faction. An example was the city of Berlin, when the wall existed. Two separate factions of civilians existed within the city divided not only by a wall, but also by political systems. Ethnic background separates factions that are defined by their heritage. An example would be the difference between the Canadians of French heritage and those of English heritage. Another difference that could be defined by this prototype is tribal. An example would be the difference between the Hutus and Tutsi tribes in Rwanda. Clearly a full implementation of all COS's would enhance the capabilities of the JTLS to represent situations where the religious and ethnic backgrounds of the population are factors. Further work in fully developing these COSSs will enhance the representation of civilian units.

A more complete representation of CA and PSYOP functionalities can be examined in follow-on studies. Many aspects of these functionalities were not

discussed so that the broad applications of this approach could be demonstrated in this study.

Few civilian behaviors are currently modeled in wargames, and clearly countless civilian group behaviors can be related to their level of well-being. However, the intent is not to change JTLS from a combat model. Civilian behaviors to be modeled must be an important component of the environment in which the military is expected to operate in the future. The changing roles and missions for employment of the military requires careful examination of the level of detail needed to portray civilian behaviors that are of military interest.

APPENDIX

The amount of acreage used for crop production in 1971 is tabulated in Table 2.[Ref. 18:pp. 9-13] These data were collected by the Food and Agriculture Organization of the United Nations.

Crop	Europe North America	Africa Asia Latin America	China Soviet Union
Wheat	63	59	95
Rice	2	99	34
Maize	48	50	15
Millet/Sorghum	8	72	33
Barley	30	17	35
Oats	17	1	13
Rye	9	1	10
Total Cereals	177	299	235

Table 2. Area of Land Producing Foodstuffs

Cereals account for between 70 to 75 percent of the world's acreage under cultivation. More land is used to produce beef than cereals, however the majority of human foodstuffs are produced from cropland used to grow cereals and other crops. Some other crops not considered include potatoes, sweet potatoes, pulses⁶, and oilseeds⁷. Oilseeds have assumed an increasing degree of importance in third world countries foodstuff production and consumption, but are not considered in this model because data on production were not available. Since the terrain in JTLS makes no distinction between land under cultivation

⁶ Pulses consist of green beans, peas, etc.

⁷ Soybeans are a common oilseed.

and grassland used to produce beef, both are considered. Table 3 tabulates the production levels for cereals and are expressed in million metric tons.

Crop	Europe	Africa	China
	North America	Asia Latin America	Soviet Union
Wheat	142	82	113
Rice	6	197	104
Maize	185	83	40
Millet/Sorghum	25	50	26
Barley	70	18	55
Oats	39	2	17
Rye	18	1	11
Total Cereals	500	443	366

Table 3. Crop Production Levels

The production levels for beef expressed in millions tons are tabulated in Table 4. Sheep, pigs and milk are not considered. Table 5 tabulates the productivity of land capable of producing foodstuffs. The method used to apply degradation

Item	Europe	Africa	China
	North America	Asia Latin America	Soviet Union
Beef	20	6	10

Table 4. Beef Production Levels

of foodstuff production for different types of terrain uses the production of the open terrain hex as the base case. The degradation factors used are enumerated below:

- Open terrain 100% production.
- Open Good Road 90% production of Open hex.
- Open Poor Road 95% production of Open hex.
- Forest Good Road 35% production of Open hex.
- Forest Poor Road 25% production of Open hex.
- Forest 10% production of Open hex.
- All Mountain hexes 5% production of Open hex.

The rationale used to evaluate open hexes is that road structure removes land area from production , reducing output. For forested hexes, roads open the forest, increasing land under production in these areas. Mountain areas are independent of roads for crop production.

Item	Europe	Africa	China
	North America	Asia Latin America	Soviet Union
Total Cereals (million tons)	500	443	366
Beef (million tons)	20	6	10
Total Foodstuffs (million tons)	520	443	366
Total Acreage (million Hectares)	177	299	235
Total Foodstuffs per Hectare (annual tons)	2.94	1.48	1.56
Total Foodstuffs per hex (annual tons)	69.3	34.9	36.8
Total Foodstuffs per hex (daily tons)	0.19	0.09	0.10

Table 5. Production Levels per Hex

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